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Increased solar ultra violet radiation and possible links to health effects in Nunavut

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Increased Solar Ultra Violet Radiation and Possible Links to Health Effects in Nunavut

By

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Abstract

Ultra violet radiation (UVR) is believed to be linked to many health problems, and numerous studies have been conducted on Caucasian populations at all latitudes. Nunavut, in the Canadian Arctic, comprises approximately one fifth of Canada's land mass and has a scattered population, the majority of which (over 70%) is Inuit. Nunavut also possesses a unique physical geography, as well as culture, which may result in its population being at great risk from UVR. Very little research has been conducted in Nunavut on the affects of increased solar UVR and possible links to health. This thesis has compiled baseline data to begin an analysis of this problem. Data are limited, therefore scenario zones were created to outline areas of greater risk and vulnerability within Nunavut. Physical factors such as albedo, solar elevation, the polar vortex, combined with Inuit cultural and genetic factors lead to the conclusion, that in terms of UVR exposure, the Inuit may be at high risk from immunosuppression and cataracts and at lower risk from skin cancer. There is a need for greater attention and education towards the population of Nunavut for protection and awareness regarding UVR.

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INTRODUCTION

1.1 The Issue

Anthropogenic climate changes are expected to have large impacts on Arctic ecosystems. Evidence supporting climate change, specifically ozone depletion and increased ultra violet radiation (UVR), has begun to mount and the need to identify and prepare for these changes has become apparent (Carson, 1996). This thesis focuses on links between ozone depletion, increased UVR, and human health in Nunavut.

The Canadian territory of Nunavut officially came into existence April 1, 1999 and encompasses the majority of the Arctic islands and mainland of the Eastern Arctic, north of 60 degrees latitude and islands in southern Hudson Bay. Its capital is Iqaluit on Baffin Island in the east. The territory has a low population density spread over many small communities in which the majority of people are Inuit. Nunavut also encompasses a vast health administrative area; all health services are presently funded and administered by the government of the North West Territories (NWT) whose headquarters are located in Yellowknife in the far west of the Territories. It will be argued that its size, make-up, and traditional lifestyle practised by the Inuit make Nunavut unique.

One of the problems with Nunavut, and the entire Arctic region, is that not enough research has been undertaken to study the effects of UVR on human and environmental health. The International Arctic Scientific Committee (IASC) has stated:

> there is not enough accurate data on the impact of health with increased solar UVB radiation in the Arctic... it is not possible for those administering the different parts of the Arctic region to get an accurate impression of the potential threat to the health of the population posed by continuous ozone depletion. There is an urgent need...to inform the population about UVB related conditions on the basis of an integrated assessment with regards to eye, skin and immunosuppression damage (IASC, 1995: 25).

The belief that an undiscovered problem exists, in terms of UVR is evident in the scientific community and warrants attention.

There have been no studies conducted in the Canadian territory of Nunavut in terms of health effects related to UVR, yet serious medical concern linking decreased ozone, increased UVR and skin cancer is present at mid-latitudes. This thesis will argue how Nunavut, and the Inuit, who comprise 72% of the population, 90% in many communities, are at risk from UVR linked health effects. Hewitt (1997: 12) explains that:

> "Risks arise from or within the situational realities of particular places and their problems. Risk embraces exposure to dangers, adverse or undesirable prospects, and the conditions that contribute to danger...risk analysis considers potential and assessed dangers. We do not have to wait for a disaster to say and do something about it" (Hewitt, 1997: 22).

In assessing the problem of increased risk on human health from UVR, the problem can be described as a hazard.

> "The concepts of hazards as external events impinging on unsuspecting people have been shed in favour of the interpretation that they emerge from interactions between people and environments" (Mitchell *et al.*, 1989: 107).

There has been little research on the hazards of UVR on the environment and people, leaving the Inuit vulnerable and at risk from UVR. There is reason to suspect from other researchers and health care workers in Nunavut (Fox 1998, Lusk 1999), that potential health effects from UVR are largely unknown, undetected, and untreated.

The hypothesis for the thesis is that the occurrence of UVR related health problems will increase, as ozone decreases.

1.2 Objectives

Proposed links between decreased stratospheric ozone, increased ultra violet radiation, geographical factors and human health effects in the territory of Nunavut are examined in this thesis. Specific objectives are:

a) Through geographical factors, establish that Nunavut is unique and complex, where risk and vulnerability, are integral factors operating in Nunavut, an ecosystem in rapid transition.

b) To establish a theoretical baseline of mortality and morbidity statistics related to UVR and health, and to ascertain trends and project future scenarios which are specific to Nunavut and its people.

c) To incorporate both traditional and Western views of health issues into the assessment, analysis, and management considerations, regarding objective (b)

d) explore options for culturally sensitive strategies in the management and education of the risks that are identified in Nunavut based on the above objectives.

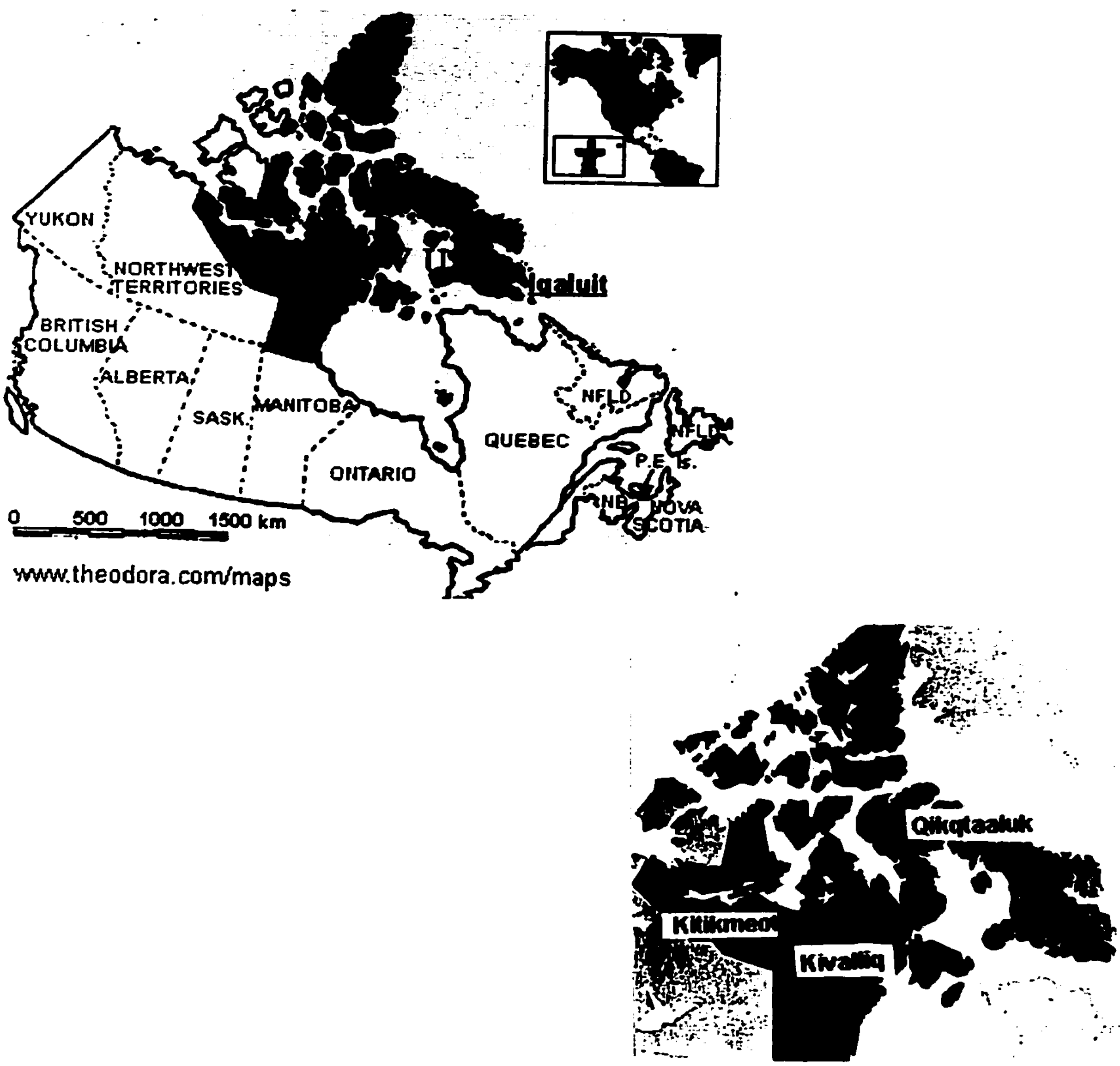
The thesis is divided into 6 sections. Section 2 discusses Nunavut, physically and politically and examines the human and social geography of Nunavut, focusing on Inuit society, culture, health, and traditional knowledge. Section 3 reviews and summarizes information regarding solar UVR and health by examining ozone depletion, ultra violet radiation, UVR and skin cancer, other health effects and geographical factors. Section 4 deals with methods incorporated within the thesis. It also describes the collection of data, and displays anecdotal, physical and health related data. Analysis occurs in section 5, where scenarios demonstrating risk and vulnerability relating to this thesis' latitudinal division of Nunavut and the effects of UVR on health are given. The final section draws conclusions and outlines recommendations for Nunavut.

THE STUDY AREA: NUNAVUT

2.1 Physical Geography of Nunavut

On April 1, 1999, as outlined in Bill C-132 assented on June 10, 1993, the eastern section of the North West Territories (NWT) became an official territory known as Nunavut. Figure 1 denotes the boundaries of Nunavut, extending from 60 degrees north latitude to the north pole, encompassing most of the Arctic islands, the eastern most parts

Figure 1. Map of Nunavut



taken from: www.theodora.com/map

of Baffin Island (62 degrees longitude) to as far west as Kugluktuk (121 degrees longitude). Nunavut is divided into three political regions: *Qikqtaaluk* (Baffin), *Kivalliq* (Keewatin) and Kitikmeot. Nunavut covers 1,900,000 square km, roughly one fifth the area of Canada. Nunavut is a vast region that is very diverse in terms of geography, where mean temperatures, snow cover, albedo (reflection of solar radiation) and sunlight play crucial roles in Inuit life and health, yet vary greatly from southern to northern latitudes within Nunavut.

The risk of solar radiation in Nunavut occurs in summer, as there are prolonged hours of sunlight and more direct zenith angles, increasing with latitude. Also, this is the time of year when the population of Nunavut spend the most time out of doors.

Iqaluit is the capital of Nunavut, located approximately 2000 km north of Ottawa. The population currently stands at approximately 4,200. Nunavut has a current population of 24,712 (Statistics Canada, 1997: 158). The population is sparsely dispersed in 27 outposts/villages. Of the 25,000 Inuit in Canada, 17,000 live in Nunavut. The population density of Nunavut is 0.01 person/square km (compared to the Canadian average of 2.9) (npc.nunavut.ca/eng/nunavut/general.html). This distribution leaves the population vulnerable, in terms of health care, as access to services may be decreased. The northern most settlement is Grise Fiord with a population of 130 at a latitude of 77 degrees north (2700km and 700km north of Ottawa and Iqaluit respectively (Baffin Region Health Board, 1998).

2.2 Political History of Nunavut

In 1962, the Government Council of the NWT passed a resolution to divide the NWT into Eastern and Western regions. In 1976, the Inuit Tapirisat of Canada proposed the formation of Nunavut (Purich, 1992). In 1982, the NWT government assembly unanimously voted on the proposition of a division of the NWT. In the fall of 1992, it was concluded that a division of the NWT would be feasible and would occur.

UVR detrimentally affects biological organisms, including humans. Increased UVR will affect the Arctic food chain, and the Inuit partially rely on country foods (wildlife that is hunted and gathered), such as seal, polar bear, fish, birds and caribou. "Reliance on country food, then, is a matter of health as well as economics" (Usher, 1982: 11). As UVR adversely affects humans and the environment, the health of Nunavut, ecologically and economically will be affected, thus inviting further research in this field.

In the past, Inuit and their ancestors lived nomadically, dispersed throughout the Arctic. This method of settlement had little impact on the land (Riewe and Gamble, 1998). This resulted in the Inuit possessing a very intimate relationship with their environment. It is therefore valuable to collect anecdotal data, in the form of traditional knowledge from the Inuit pertaining to increases in UVR and its effects.

Grygier (1994:189) describes the history of health care and the Inuit. Missions and traders were the first to offer western health care to the Inuit, as well as the RCMP by 1920. In 1922 the Northern Health Service began supplying health care, which was taken over by the Indian Health Service of the Department of Indian Affairs in 1927. That was subsequently replaced by Indian Health Services in 1936, which was transformed to the Department of Health and Welfare (1945). In 1955, Inuit hospitals were centralized and in 1970 the NWT took control of health care in the Arctic.

Each board or district is responsible for providing various health services for each community (listed in Appendix A). Within each regional subdivision of Nunavut, there are still very large distances between these dispersed communities. The management of health care in Nunavut is an expensive and challenging task, as vast distances have to be covered for a small sparsely distributed population in a harsh climate.

2.3 Human Geography of Nunavut

The culture and society of the Inuit vary greatly from the cultural norms of the non-Arctic Canadian population, the majority of whom live near the Canadian-American border. These differences are vital when attempting to research an issue, such as UVR effects on health, as methods, data and research (population makeup, size) used in southern Canada may be completely inappropriate in Nunavut. This section will briefly describe the society and culture of the Inuit. This knowledge will be applied when making recommendations for protection and education regarding UVR and human health.

a) Inuit society

Inuit law was developed during the time period when there were no year-round permanent settlements. Harmony, peace and equilibrium were the basis on which laws were formed (Inuit's Women's Association of Canada (IWAC), 1990: 7). Hostility and aggression are the most deplorable emotions, tolerance and patience are the most admired (Condon, 1983: 195). In such a non-confrontational society, leadership, for the majority, is carried out by example (IWAC, 1990: 7). If leaders express views too strongly, they risk the impression of being too bossy or pushy, and consequently, they are gossiped about. The Inuit have evolved into a largely egalitarian society, where high regard is placed on the rights of the individual, where one can live free from the interference of others (IWAC, 1990: 17).

Attitudes of emotional constraint and physical mobility are instilled in the Inuit from childhood. From the time a child can walk, they are free to explore their world as they please (Condon, 1983: 77). This freedom may be of concern in terms of UVR exposure, as there is no parental supervision to ensure precautions for protection from the sun. Little discipline is exerted over children, as disciplining for misbehaviour is generally limited to teasing and chastising by parents (Condon, 1983: 78).

b) Inuit health

The health care system in Nunavut is administered by the government of the North West Territories, eventually to be transferred to the government of Nunavut. The population and number of beds and bassinettes for each of the 3 districts in Nunavut is outlined in Table1. Hospital beds will be used as an indicator to the accessibility and availability of health care.

Table 1. Hospital beds/bassinettes per person in Nunavut.

District	beds/bassinettes	population	beds/pop'n	bassinette/pop'n
Baffin	66/24	13218	1/200	1/550
Keewatin	24/07	6868	1/286	1/981
Kitikmeot	15/04	4626	1/308	1/1157
Nunavut	105/35	24712	1/235	1/706

Source for population: Statistics Canada, 1997:158
Source for beds and basinettes: Statistics Canada, 1993:48

Canadian hospitals average 138 beds (Statistics Canada, 1993: 8), with 1 bed for every 168 people (Espenshade, 1995: 3). There is 1 bed for every 235 people in Nunavut. It may be suggested that Nunavut is a marginalized territory, which may be under serviced.

There have been complaints that the system for health care is "a top-heavy corporate-like administration" (Baffin Region Profile(BRP), 1994: 53). Forty percent of the Baffin regional health board are non-health care professionals, involved in administration or health care support. Whether this is the proper ratio is not the issue; the issue of importance is the fact that people in the Baffin region perceive a top-heavy organization that does not meet the needs or satisfaction of the people it serves. It is not known if this is the view of the majority or a vocal minority. Public discussions published by the Baffin Region Health Board (BRP, 1994), health needs assessment profile, have outlined concerns the public has.

A further concern is the continuity of care that the Inuit, and the people of Nunavut receive. In many cases there are specialists, such as ophthalmologists and dermatologists and doctors who rotate through the north (BRP, 1994: 56, Decker, 1999). The lack of continuity of doctors and specialists may lead to lower quality health care and increased risk, as patient progress may not be effectively monitored when doctors leave after short stays. A new doctor may be concerned for patient health, but cannot review the case histories and files of all past patients. People may not have the means to return repeatedly to health care centres from outlying regions. The area that each health care centre services is very large, with a dispersed population and no roads, making mobility more difficult than what would be characteristic in southern Canada.

A study conducted by Diverty and Perez (1998: 50), examined the perceptions and quality of health care received by the Native and non-Native residents of the NWT and the Yukon in 1994/95. The study surveyed 20,725 households in the territories, and compared results to provincial averages. The table below demonstrates the averages of populations and their perceptions of health care in the NWT and provinces.

Table 2. Perceived health care in the NWT.

Perceived Health	Native NWT	Non-Native NWT	Provincial Avg.
excellent/good	47	75	63
poor/fair	12	6	10

Source: Diverty and Perez, 1998: 51

This survey finds that Native populations have a lower perception of the quality of health care received compared to non-Native and provincial respondents to the survey. History has shown that Native peoples have received sub-standard health care (Grygier, 1994: 134), and that sentiment, at least partially, continues today according to Diverty and Perez. Table 3 illustrates the percentage of Natives that have had contact with various health care professionals.

Table 3. Native use of health care.

Health Professional	Native NWT	Non-Native NWT	Provincial Avg.
Doctor (G.P.)	36	54	77
Optometrist	34	35	35
Nurse	41	20	7

Source: Diverty and Perez, pp.51, 1998: 51.

In Native populations, there is less physician than nurse contact. This may be dependent on a number of variables. Most health care delivered to the Inuit is received at health care stations (Diverty *et al.*, 1998: 54). Health stations have more nurses, many receiving additional training which allows them to diagnose and administer treatment. There is only one doctor for every 1,068 NWT residents, compared to the Canadian average of 1 for every 476 (Diverty *et al.*, 1998: 54). Lower doctor contact may lead to a lower perception of health care, as only nurses diagnose patients. This may increase Inuit vulnerability.

Co-operation is needed between traditional healers and western health staff (Waldram *et al.*, 1995: 205). Leenan (1996: 4) states:

> doctors (health care professionals) and patients must behave as partners...patients who are informed and involved...with their rights respected, recover more quickly and have shorter stays in hospitals. Training health care professionals regarding traditional beliefs (in Nunavut), will aid in their adapting treatment, diagnosis and education to suit their patients, producing an effective health care system.

Inuit health is a "state of being of both the individual and the community, that is attained through responsible social action" (Borre, 1994: 10).

Local traditional knowledge, in the form of healers, should be incorporated into health care for populations with non-scientific medical backgrounds, as argued by Kahssay (1996: 4). Scientific medical knowledge programs have dominated these communities. Whether or not healers are effective in treating medical ailments is not the entire issue; trust of the healers, accessibility and affordability, are also important within the community (Kahssay, 1996: 7). Healers may be accessible to more people, and if incorporated into the medical services infrastructure, can be trained in certain techniques of western medical needs and practices, and consequently, assist in public health initiatives regarding UVR (Kahssay, 1996: 7).

The World Health Organization of the United Nations states, that "adequate importance to the utilization of traditional systems of medicine" should be encouraged by governments (Zhang, 1996: 4). Governments should exercise caution, with openness, and critically examine the benefits of traditional medicine in communities with high Aboriginal populations, such as Nunavut (Zhang, 1996: 4). Individuals are dependent upon production, distribution and consumption of country foods to maintain health (Borre, 1994: 11). For hunters to maintain good health, they must share their catch and take an appropriate mix of animals (Borre, 1994: 11). This culture may be affected by UVR and health effects in terms of impacts on traditional country foods and consequently the harvest and its distribution.

An Inuit diet based on the consumption of country foods may consist of: seal, whale, caribou, salmon, whitefish, and meat and fat from (to a lesser extent) arctic hare, ptarmigan, polar bear, arctic fox, musk-ox, and other birds, mammals and fish, along with small portions of berries and herbs (IWAC, 1990: 20). The effects from UVR on these foods is largely unknown. Large quantities of blubber, oil and fat are consumed, usually raw, frozen or aged, from these staples to provide heat-producing energy to the body. In the Arctic environment, the basis for survival is remaining warm.

The nutritional value of country foods is clearly evident in the following table, that compares protein and fat contents of various foods per 100g of each meat.

Table 4. Nutrition values of selected foods/100g of meat.

Country Food Type	Protein (g)	Fat (g)	Store Food	Protein (g)	Fat (g)
Seal	32	1.8	Chicken	20	13
Walrus	27	12	Pork	12	45
Whale	24	0.7	Lamb	16	28
Caribou	27	1.2	Beef Steak	16	25
Polar Bear	26	3.1	Hamburger	16	28

Source: Condon, 1983: 106.

If UVR negatively affects Inuit country foods, the Inuit may be forced to consume more southern foods, with possible repercussions toward Inuit health.

In the Arctic summer, the sun shines for close to 24 hours a day. During this period, the Inuit sleep very little (3 to 4 hours per night), yet, awake refreshed (Condon, 1983: 142). They refer to this sleep pattern as their "summer buzz" (Decker, 1999). This is a time of great activity out of doors and therefore great risk of UVR exposure.

Skin type, hair and eye colour are all believed to be factors in susceptibility to disease related to UVR exposure. Lighter or fairer the skin, hair and eye colour, result in greater risk regarding UVR effects and skin cancer. Studies from various latitudes illustrate fairness of skin as a factor in skin cancer development (Johnson *et al.*, 1998: 424; Gilliland *et al.*, 1998: 1769; Khwsky *et al.*, 1994: 375; Gutman *et al.*, 1993). Inuit skin type is considered type III. Hair and eye colour are brown with darker skin for type IIIs, where a type I has light skin pigmentation. In the Johnson *et al.* study, 47% of the melanoma patients had type III skin, while 61% had brown hair and eyes, leaving the Inuit in high risk.

Higher rates of skin cancer mortality, diagnosis at advanced stages, and less appropriate treatment were more common for minority groups (African American, Hispanic, Native), compared to white populations (Gilliland *et al.*, 1998: 1769). Khwsky concluded that 60% of NMSC (non-melanomic skin cancer) cases could be attributed to sun exposure, and 45% could be attributed to skin colour/type (Khwsky *et al.*, 1994: 375). These studies are not at latitudes or climates comparable to Nunavut, however, the skin type of cases are very similar to Inuit skin types. These studies show that NMSC and MM skin cancer have lower incidence in darker skinned populations, but when they occur they tend to be more deadly than previously thought.

"Changing environmental conditions are often responsible for viral traffic" (Waldram *et al.*, 1995: 43). As UVR exposure to the skin has been demonstrated to be an immunosuppressor (Armstrong, 1994: 873), new viruses could migrate to the Arctic and have serious detrimental effects on a population that has not been exposed to foreign viruses. Global warming may also play a factor in terms of the migration of vector-borne disease (Martens *et al.*, 1995: 195). With increased UVR resulting in the possibility of a weakened immune system, the Inuit may be more susceptible to vector-borne bacteria, parasites and diseases (Martens *et al.*, 1995: 195).

c) Culture and health

The traditions of healing and health in Inuit culture are centred on foods ingested, how food is acquired and prepared, the relationship of the people with the land, and the balance of the mind, body and soul. The concept of health for the Inuit is very different than that provided by western medicine. The concept of health includes the soul, mind and body, as well as the social well-being of the community (Abdussalam *et al.*, 1996:1)

In many cultures, certain foods are relied upon, for sustenance and/or healing powers, and are therefore of cultural significance (Abdussalam *et al.*, 1996: 1). For the Inuit, the seal is central in cultural and economic significance (Borre, 1990); seal is taken for its meat, oil, broth, skin and is used to treat illness and prevent sickness and is a staple in the Inuit diet (Borre, 1990, 1994). Seals, as well as caribou are threatened by UVR exposure, also threatening Inuit culture (Borre, 1994: 2); they may be used as an example to spread the message of the possible dangers of UVR.

d) Traditional knowledge of climate

Inuit observations involving the sun and sky have described a difference in the colour of the sky and the strength of the sun (Fox, 1998: 100). Inuit residents have begun to sustain sunburns (erythema), a recent phenomenon starting in 1992 (Fox, 1998: 100). Hunters who have spent their lives in the 24 hour sun of the Arctic are only now experiencing sunburn. Inuit descriptions of the change in the sun's strength ("the heat of the sun is sharper now", "a stinging or sharper sun") are not related to a rise in temperature (Fox, 1998: 101). UVR increase is not related to temperature change. This could be the reason that this perception has coincided with an increase in requests for sunscreen at the Igoolik nursing station (Fox, 1998: 101). In the past, people talked of how they were able to look directly at the sun on cloudless days; now it hurts peoples eyes and they are advised by medical services to wear sunglasses (Hudson's Bay Program, 1995). UVR will cause erythema and pain in the eyes, but will not increase the rate of melting of snow or ice, and will not increase temperature.

In the summer, hunting can occur for the majority of the hours in the day, as the sun does not set. A very critical time for exposure to UVR is when people are out on the land in direct sunlight lasting 24 hours. As seals and other country foods are staples in the

Inuit diet, time spent on the land can prove hazardous from UVR. Condon (1983: 60) provides a description of typical hunting behaviours/patterns for months that have sunlight hours, showing the increase of UVR risk as summer progresses:

March:	hunting becomes more frequent as daylight hours increase; hunting for fox and caribou.
April/May:	hunting activity increasing, days lengthening, ice and snow still present.
June:	sunlight for 24 hours/day, wage-earners hunt after work, through the early morning hours, hunt geese and ducks.
July:	people leave settlements to live on the land.
August:	summer ending, days shortening, less activity outside.

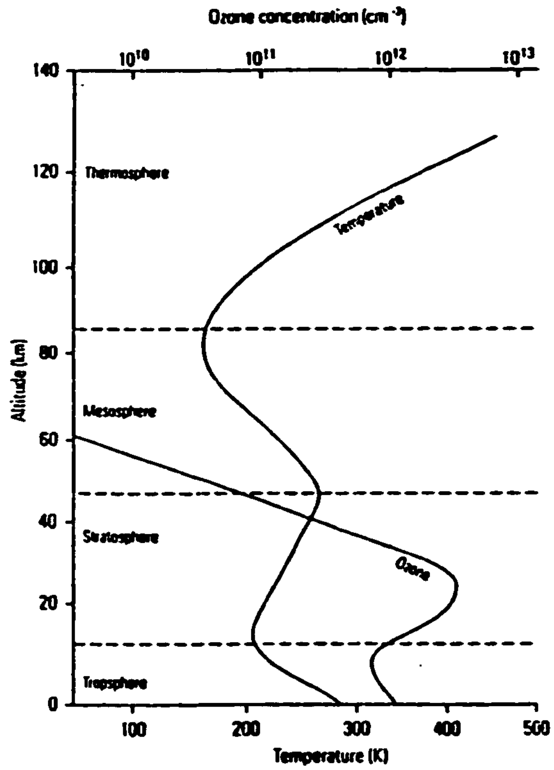
The summer temperatures can reach into the 20 degree Celsius range, and as less clothing may be worn, there is less protection from the sun's UV rays.

FACTORS PERTAINING TO UVR

3.1 Ozone Depletion

In 1974, it was discovered that chlorine molecules destroy ozone (Stolarski, 1974), and later that chlorofluorocarbons (CFCs) release great quantities of chlorine (Molina and Rowland, 1974). Further studies reported on the relationship between ozone and chlorine (UNEP 1977, UNEP 1985, Farman 1985, WHO 1986). Ozone consists of 3 oxygen molecules, and is concentrated in the stratosphere between 25 and 45 km, forming the ozone layer (Environment Canada, 1995: 2, Brassard, 1992: 2). Figure 2 denotes atmospheric boundaries and ozone concentration.

Figure 2. The vertical distribution of atmospheric ozone.

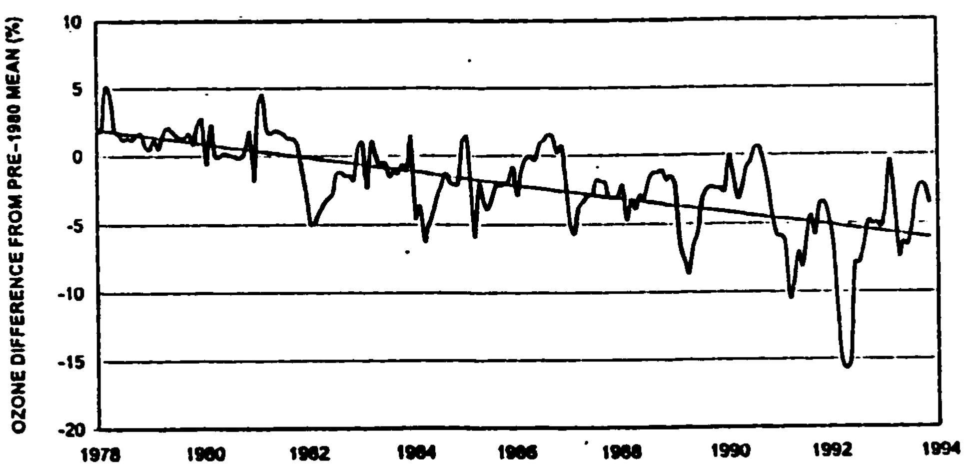


Source: taken from Drake, 1995: 2.

In 1985, British scientists announced the discovery of a large thinning of the ozone layer above Antarctica. This thinning was believed to have begun in the early 1970s. Later that year, Canadian researchers, focusing on the Arctic, also found, to a lesser extent, a thinning ozone layer over the north pole (Environment Canada, 1995: 2). A thinning ozone layer caused concern because its association with UVR, which ozone absorbs, and the link between increased UVR to negative health impacts in biological organisms (Kerr *et al.*, 1993, Environment Canada, 1995: 1). Furthermore, the Arctic region has seen a 12% decrease of ozone per decade, compared to a 5% loss at mid-latitudes and a 65% loss in Antarctica (Environment Canada, 1997: 12). These figures vary, as ozone levels were 30% and 45% below pre-1980 levels in the springs of 1996 and 1997 respectively, in the Arctic, compared to a 7% decrease at mid-latitudes (Environment Canada, 1997: 12).

Figure 3 demonstrates the total ozone trend from the latitudes of 30 degrees north to 65 degrees north, from 1978 to 1994. In that time there has been an approximate

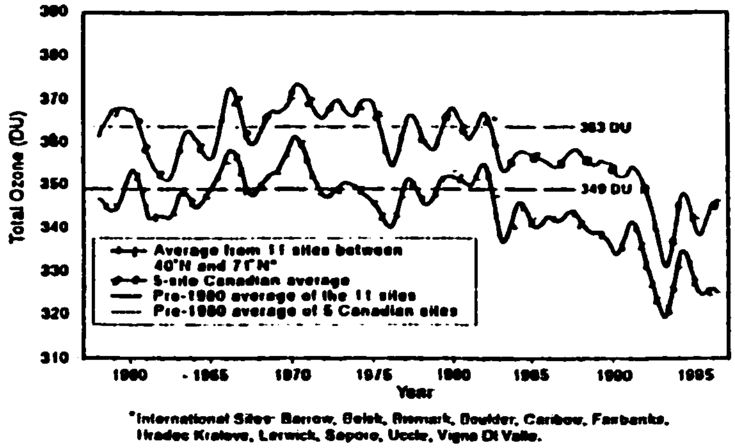
Figure 3. Total ozone trends, 30 to 65 degrees north latitude.



Source: taken from Wardle *et al.*, 1997: 27.

decrease from pre-1980 averages of 8%. Figure 4 illustrates the averages of total ozone from Canadian stations at latitudes ranging from 40 to 71 degrees north, between 1960 and 1997. The trend of total ozone from pre-1980 averages to 1995, the 5 Canadian sites shows a loss in Dobson units of 6%. The Dobson unit is a form of measurement: 1 milli-centimeter of column ozone equals 1 Dobson unit; the atmospheric average of ozone is

Figure 4. Total ozone over 5 Canadian sites and over 11 other mid-latitude sites.



Source: taken from Environment Canada, 1996: 15.

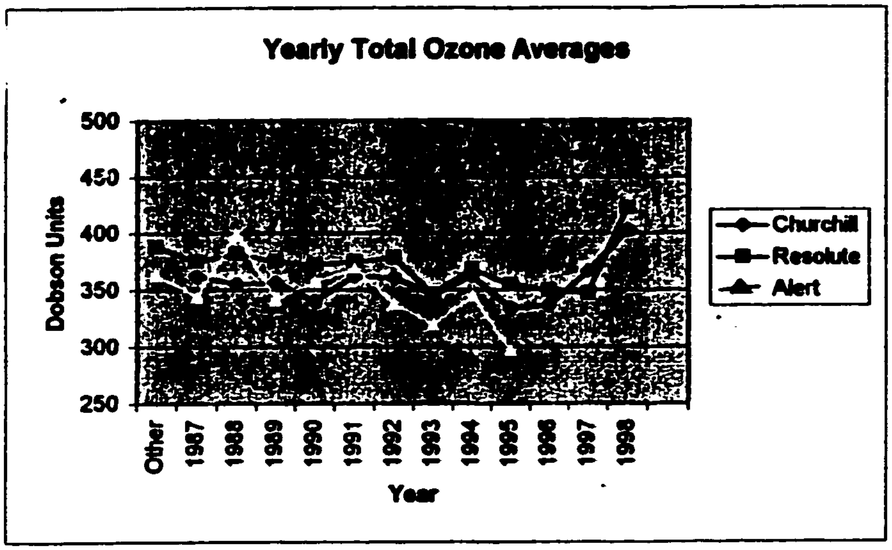
300 Dobson units (Drake, 1995: 2). Total ozone averages from two Canadian sites, Resolute and Churchill, from pre-1980 levels to 1996, showed a decrease of 5 to 6% of total ozone annually (Wardle *et al.*, 1997: 32).

Figure 5 illustrates the data from the World Ozone Data Centre (WODC, 1999) in Toronto, for the only 3 stations in the Eastern Canadian Arctic and Nunavut, which have consistent data over time.

Alert	- latitude 82 degrees north, in the high Arctic
Resolute	- latitude 74 degrees north, in the mid Arctic
Churchill	- latitude 58 degrees north, 1.25 degrees south of the southern Nunavut border.

Data were accessed from Environment Canada's from internet site: ftp:woudc:woudc*@ftp.tor.ec. gc.ca/wodc/document (Hare, 1999). The data consisted of daily averages of total column ozone (Dobson units) measured at each site with a Brewer-Spectrophotometer. Data were retrieved for the years 1987 to 1998, for Churchill and Resolute, and 1987 to 1995 for Alert. Churchili is in northern Manitoba and was used as a station, as it was the only station in, or close to Nunavut that had recorded ozone data available south of Resolute. The majority of the data collected were observed in daylight, and are displayed in Appendix B

Figure 5. Total ozone values, yearly means.



Source: World Ozone Data Centre, 1999

As summer progresses, total ozone decreases. All stations demonstrated a loss of ozone of at least 25 Dobson units from pre-1970 levels. Once again, in August, losses of at least 25 Dobson units are recorded compared to mid-1980 or pre-1970 averages. 1998 is an outlier year, as data was only collected from January through to April, traditionally times of higher concentrations of ozone in the atmosphere.

Ozone absorbs all UVR (and other radiation) with a wavelength less than 290 nanometers (nm) (1 nm is equivalent to 10^{-9}m), 90% of wavelengths less than 304 nm, 50% of the UVR at 314 nm and 1% at 339 nm (Armstrong, 1994: 875). Without the protective ozone layer to absorb solar UVR, life on earth would not exist in a form that we now know. Models generated today, using data regarding produced, released and existing ozone in conjunction with the "Montreal Protocol" and its various amendments predict that UVR levels reaching the ground will peak in 2010 and plateau until 2040 (Armstrong, 1994: 877). This means a 5 to 30% rise in the annual UV irradiance compared to levels in 1970 (Armstrong, 1994: 877). This has significant impacts for human and ecological health on earth..

Chlorine released from CFCs, HCFCs and halons can remain in the atmosphere for 100, 15, and up to 15 years respectively. Each chlorine atom released from CFCs and HCFCs chemically breaks down between 10,000 and 100,000 ozone molecules before it decomposes (Environment Canada, 1995: 5). Halons release bromides, which break down ozone in a similar way to chlorine, but have a shorter life span in the atmosphere.

The discovery of anthropogenic ozone-depleting processes resulted in rapid global action in banning these chemicals. In 1985, the United Nations Vienna Convention was ratified, providing a framework for monitoring, research and scientific assessment of the ozone layer. Amendments to the Convention were declared in Montreal in 1985, and ratified in January of 1989, further revised in London in June of 1990, and lastly in Copenhagen in 1992, further increasing the rate of reduction in the production and use of ozone depleting chemicals (Smith and Vodden, 1989). A significant factor in promoting change was the action of the Dupont corporation (Haas, 1991: 231). Dupont's reaction was, scientifically, hard to explain, as establishing links between the environment and health is difficult, as there are many variables. Linking ozone depletion and UVR to health problems can only be presented in levels of probability, which is why using the concepts of risk and vulnerability are appropriate. Dupont produced 25% of global CFCs. In 1986 they agreed for the need of CFC controls, and in 1988, discontinued CFC production. This action forced the entire chemical industry to follow suit or be left behind in terms of receiving a share of the CFC-alternative market (Haas, 1991).

Ozone is created in greatest quantities at the equator, and through atmospheric circulation, reaches the poles where it is destroyed (when at least one oxygen molecule is lost) (Drake, 1995). The destruction of ozone occurs naturally, as ozone molecules are in a constant state of destruction and creation. This equilibrium has been disrupted with the introduction of anthropogenic chemicals into the atmosphere. Due to colder temperatures present over Antarctica and the resulting formation of more and longer lasting polar stratospheric clouds, there is greater ozone loss. These clouds provide a suitable surface for the chemical reactions between ozone and chlorine, increasing rates of ozone destruction over rates of creation.

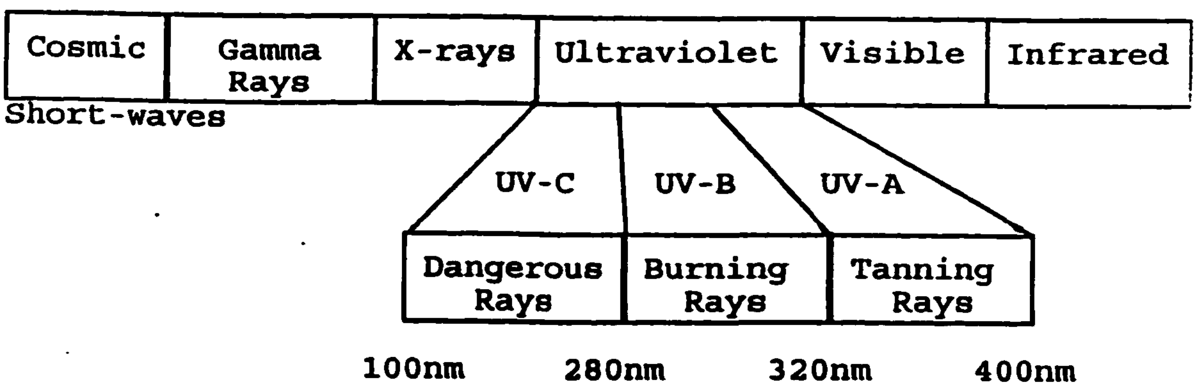
Ozone thickness changes with the seasons. The greatest thinning of ozone in the Arctic occurs in spring, between February and April (Fioletov *et al.*, 1997: 2707). Ozone levels may vary greatly day to day taking into account high altitude winds, solar activity and volcanic activity.

3.2 Ultra Violet Radiation

UVR is a thin band situated on the electromagnetic spectrum and is defined by having a wavelength between 360 and 250 nm (Figure 6). This band is divided further into 3 sub-bands; UVC has a wavelength from 100 - 280 nm and is completely absorbed by the atmosphere; UVB: 280 - 315 nm is absorbed by ozone and is biologically damaging; UVA: 315 - 400nm is not readily affected by ozone and has been linked to a lesser extent to biological damage (Lloyd and Im, 1994: 330). Visible light lies at 400 to 780 nm on the electro-magnetic spectrum. Although UVR can be biologically damaging, specifically, altering cellular DNA, it is necessary for certain bodily functions

Figure 6. The electro-magnetic spectrum.

UV-A	320 - 400 nm (nanometers)
UV-B	280 - 320 nm
UV-C	100 - 280 nm



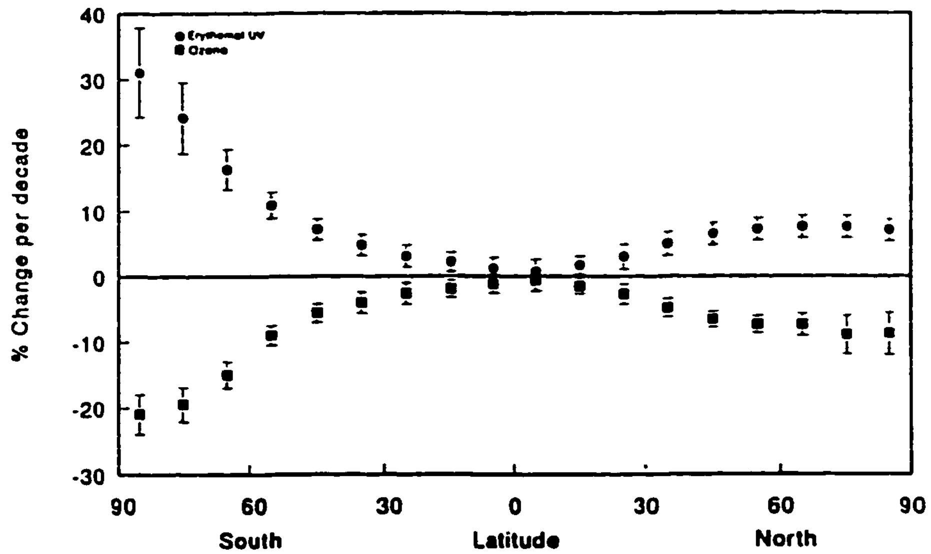
Source: taken from the Canadian Centre for Occupational Health and Safety, 1994: 1.

(Leffell and Brash, 1996: 56). In humans, for example, UV reacts with cholesterol in the skin and photochemically produces vitamin D, a necessary function, as generally all vitamin D requirements cannot be fulfilled by diet alone (Armstrong, 1994).

As ozone concentrations decrease, shorter and greater quantities of UVR enter the atmosphere. Figure 7 illustrates the percentage decrease of ozone compared to increases in UVR (in erythemal UV irradiance at ground level), through latitudes 90 degrees south to 90 degrees north. These data examine ozone and UVR levels from 1979 to 1992. Ozone depletion almost identically mirrors increased levels of UVR reaching the ground. At latitudes 60 to 90 degrees north, there is a 10% total loss of ozone, and a 6 to 7% increase in UVR irradiance.

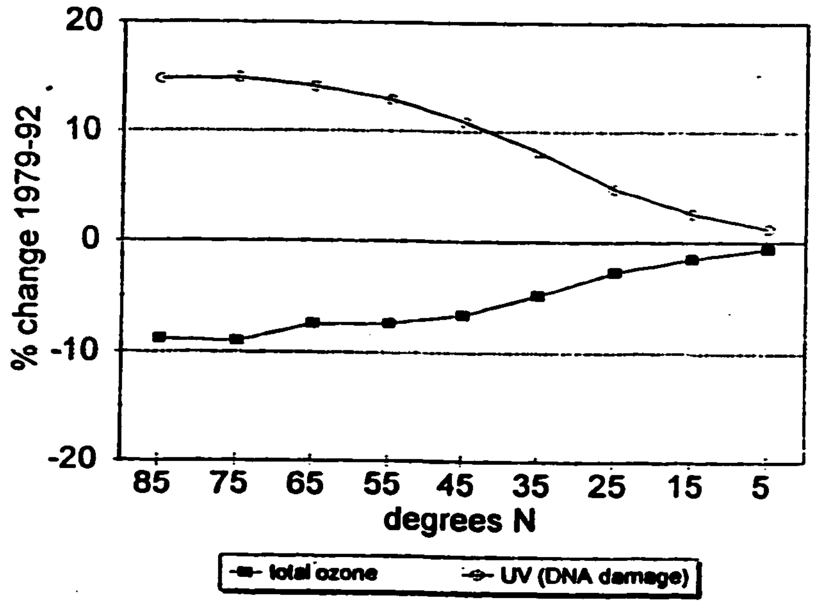
Figure 8 graphically describes the percentage change in ozone in relation to measures of UV irradiance (predicted biological damage that may occur as a result of increased UVR exposure). The higher the latitude, the more significant the effects, for example, at 85 degrees north, a 9% loss of ozone corresponds to a 15% increase in UVR.

<u>**Figure 7. Percent change in ozone comparing UV irradiance at latitudes, 1979-1992.**</u>



Source: taken from Armstrong, 1994: 876.

Figure 8. Ozone depletion and estimated UV change, 1979 - 1992.



Source: taken from Aase and Bentham, 1994: 132.

As ozone decreases, greater quantities of UVR reach the ground and UVR occurs in shorter wavelengths, which are more biologically damaging (Wulf, 1994: 417). The shortening of UV wavelengths is due to a decrease in the filtering effects of less atmospheric ozone (Wulf, 1994: 417). A 1nm shift in UVR to a shorter wavelength is equal to a 15% increase in the biologically effective dosage (BED) of UVR; a 5nm shift doubles the BED. Therefore, a small decrease in ozone may have a large impact on BED and hence, biological organisms (Wulf, 1994: 418).

Figure 9 demonstrates the percentage increase in ground level UVB flux from corresponding percentage decreases of ozone; a 10% loss of ozone equals a 5% increase in ground level UVB. Figure 10 denotes the biologically accumulated dosage (BAD). BAD is the BED summed over time of UVB as a function of ozone loss, which does not appear linear. A 10% decrease in ozone results in a 25% increase in the BAD, a measure of how organisms respond to cumulative ground level UVR (Lloyd and Im, 1994: 332).

Figure 9. UV-B flux as a function of ozone loss.

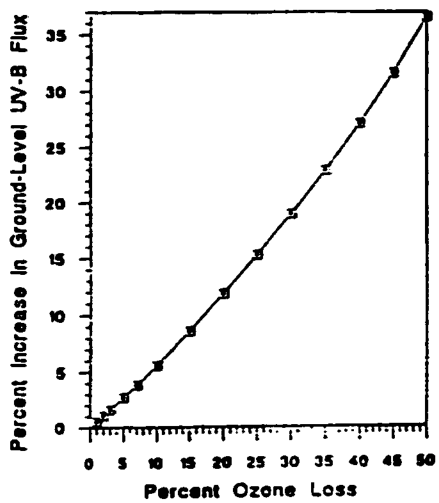
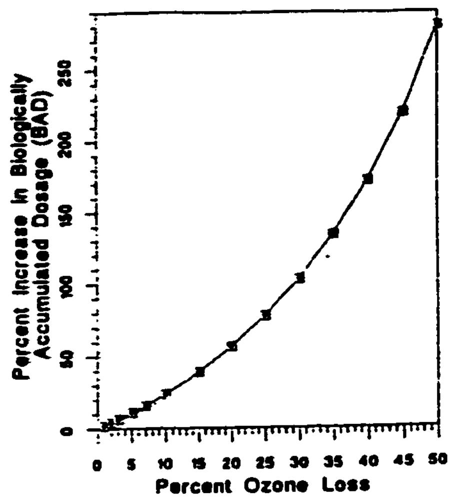


Figure 10. BAD of UV-B and ozone loss.



Source: figures 9 and 10 taken from Lloyd and Im, 1994: 334.

UVR affects organisms other than humans, such as plankton. Plankton consists of aquatic life that includes macroscopic organisms, such as young fish, crabs, and shrimp. Plankton is very sensitive to UVR. Increased UVR will disrupt the aquatic food chain. This disruption begins at the base of the food chain with zooplankton and phytoplankton, which live in the top layers of ocean waters, where they are most vulnerable to the genetic damage caused by UVR (Hader, 1994: 157). UVR bleaches the photosynthetic pigments in the phytoplankton, reducing oxygen output and carbon dioxide input, limiting the effectiveness of this carbon dioxide sink and contributing to global warming (Hader, 1994: 156). This disruption of the food chain affects organisms, such as shrimp, fish, seals, and humans.

Terrestrial animals (caribou, birds, polar bears, seals, fish) are also affected by UVR and suffer similar health problems as humans, such as eye damage and immune suppression (Environment Canada, 1995: 4). Early studies suggest that feathers of birds suffer photodegeneration from UVR exposure (IASC, 1995: 18). This is reason for human concern, especially in Nunavut, as the Inuit rely on country foods as staples in their diet. There are other factors in regard to UVR that have unknown effects. UVR in the lower atmosphere can photochemically react with chemicals associated with global warming and climate change. The full effects of UVR on humans and the rest of the ecosystem is still unknown (Environment Canada, 1995). For animals in the Arctic, the main risk of UVR lies in damage to the eye, not the skin, as Arctic animals have adapted thick coats for insulation (IASC, 1995: 18).

Current research suggests that UVR affects plants in a number of ways. Pollen is affected by UVR in terms of production, morphology, size and distribution, and this impairs pollen viability and is therefore detrimental to a plant's reproductive success as a species (D'Antoni *et al.*, 1994: 91). UVR affects early plant development and has negative impacts on photosynthesis, carbon assimilation rates, growth, defense mechanisms against disease (D'Antoni *et al.*, 1994, Drake 1995), the height, biomass and yield of coniferous trees, possibly impacting the limited forested areas of Southern Nunavut (Tevini, 1994). Research regarding UVR effects on plants have taken place on agricultural crops, yet there is scant data on animals and very little on the Arctic ecosystem (IASC, 1995: 18). Arctic plants are considered more vulnerable to UVR exposure then plants at mid-latitudes; due to lower Arctic temperatures, repairing the damage is a slower process in the Arctic (IASC, 1995: 18).

A measure developed to quantify UVR links to biological organisms is the radiation amplification factor (RAF) (Coohill, 1994: 61). This measure attempts to predict increases in health problems associated with 1% decreases of ozone. For example, with a 1% loss of ozone, there is an expected 2% increase in skin cancer, a 2 to 3% increase in non-melanomic skin cancer, a 1 to 2% increase in cataracts, and a 1 to 2% decrease in immune system response tests (Coohill, 1994: 61).

In humans, cellular damage from UVR is either short term or long term. Short term damage includes tanning and the inhibiting of the body's synthesis of vitamin D. Long term damage includes erythema (sunburnt skin) and tumour growth. Removing one's self from direct sunlight exposure is not always an effective means of protection.

Much of the UVR that reaches the ground scatters, therefore, shade is not always an effective form of protection from UVR. High levels of UVR may pass through clouds, depending on the cloud type and clothing (dependent on the material, thickness, and type of weave) (Weinstock, 1992).

A question that requires future research, is how viruses and bacteria will be affected by increased UVR exposure, and how those possible changes may in turn affect plants and animals. UVR exposure has been linked to many human health problems, such as skin cancers, immune system suppression and eye damage (Environment Canada, 1997: 5). It is a difficult task to link health problems to environmental factors, as there are many interconnected variables. There is a strong link from evidence collected in experiments with animals and humans, between UVR and skin cancers, cataracts and immune suppression.

3.3 Skin Cancer

Ultra violet-B (UV-B) radiation is the most biologically damaging band of UVR and is linked to the development of skin cancers in humans. The skin is the first layer of defence for our bodies against environmental elements. In February 1992, the *International Agency for Research on Cancer* concluded that,

> there is sufficient evidence in humans for the carcinogenicity of solar radiation. Solar radiation causes cutaneous malignant melanoma and non-malignant melanomic skin cancer (Armstrong, 1994: 879),

and Environment Canada followed in 1995 (1995: 3).

Skin cancer rates decrease with increasing pigmentation, as less UVR can penetrate to deeper levels of the skin. Even with pigmentation, outside factors play a role in the sensitivity of the skin to sunlight, such as: skin disorders, the use of antibiotics (tetracyclines and sulpha drugs), cosmetics (dandruff shampoo), drugs used for cancer treatment, diuretics, anti-nausea drugs, and oral contraceptives, all of which enhance the effects of UVR on the skin (Rinzler, 1991: 156). UVR and skin damage are becoming more prominent in society (Rinzler, 1991; 156). The effects of skin cancer to those who have not been affected may seem trivial and a cosmetic inconvenience. The reality is, that skin cancer can not only be economically expensive (the costs of diagnosis, long or short-term treatment, and medical procedures), but also emotionally damaging, as a common site of occurrence and disfigurement is the face (Armstrong, 1994). Factors influencing skin cancer development include the presence and number of nevi (skin moles), density of moles and the latitude at which one lives (Environment Canada, 1995; 92).

Skin cancer is grouped into three main categories, all at epidemic status, i.e. where the actual number of cases has become greater than the expected number (Goldman, 1998: 80). Basal Cell Carcinoma (BCC) occurs in the epidermis, and Squamous Cell Carcinoma occurs in the squamous layer of cells above basal cells. BCC and SCC incidence rise with the frequency and severity of sunburns, age, and fairness of skin (Environment Canada, 1997: 93). BCC appears as a hard raised, red-gray pearly sore that usually does not spread and in most cases is easily treated and cured (Baxter, 1990). The vast majority of BCC and SCC occur on the head or neck, and UVA, as well as UVB, are believed to be causal factors in its development (Elwood 1992, Jones 1989). Studies on BBC have been conducted regarding reoccurance and immunosuppression from UVR (Levi *et al.*, 1998). A study conducted by Rosso *et al.* (1996: 1447), states, that over 70,000 hours (8 years) of cumulative sun exposure in a medium skinned person (fairer than the Inuit skin type), are needed to produce SCC development. As a tumour continues to grow in size and depth, it has metastatic (the spread of cancer cells from the original tumour to other parts of the body) potential (Goldman 1998, Baxter 1990).

The key to survival is early detection, evaluation and aggressive treatment (Goldman, 1998). SCC is a high risk tumour, with growth promoted by UVR, that suppresses (p53), a tumour suppressing gene in the body which allows for increased levels of tumour development.

Malignant melanoma (MM) is the most deadly type of skin cancer. From 1970 to 1988 in Canada, the incidence of MM has increased 160%, with mortality rising 51% (Berkel, 1992: 10). In Denmark, MM incidence has risen 400% in the last 30 years (Wulf, 1994: 418). The incidence of MM in men in Canada is now the third highest of all cancers, rising 2.7 per year (and rising 0.6%/year in women) (Canadian Dermatology Association, 1996: 2). MM has traditionally had its highest incidence rates in Caucasian populations and has been rarer in darker skinned races (Elwood, 1992). The risk of melanoma development is not only reliant on skin type, but from the regularity and timing of UVR dosage. An example of high risk is a subject with a low level of chronic exposure, but high levels of intermittent intense exposure. Nunavut, for half of the year receives almost no sunlight and for the other half 24 hours of exposure is possible, leaving the possibility for high risk in terms of both intermittent and cumulative exposure.

Clark's Level of Invasion is a measure of tumour development for melanoma, illustrated in Appendix C. If melanoma is diagnosed at stage I in the skin, the probability of surviving 5 years is approximately 85% (Brown, 1997: 113). However, if metastases to the lymph nodes has occurred, 5 year survival probability drops to 40%, and if the cancer has spread beyond the draining lymph nodes, there is a 20% chance of 5 year survival (Porras *et al.*, 1997: 95). Factors determining survival when a tumour is discovered include size and depth (a tumour < 1 mm vertically is unlikely to metastasize) (Reed *et al.*, 1997: 137).

Research has shown significant increases in malignant melanoma rates in Caucasian populations (this may be due to increased rates of reporting and awareness), more so than populations of darker skin types. These findings may result from the fact that little research has been done on melanoma rates for non-Caucasians. This is the case in Nunavut. There have been no specific studies conducted on the Inuit and skin cancer, yet cases of skin cancer have been reported.

At northern latitudes, it may be expected that a high latitude combined with lower UVR intensity would result in low risk and lower occurrence of skin cancer. This is not necessarily the case, for example, countries at higher latitudes in Europe have some of the highest rates of skin cancer. Table 5 lists the percentage increase of specific Nordic country's melanoma incidence rates/100,000 from 1978 to 1987.

Table 5. Rate of Increased Occurrence of MM in Selected High Latitude Countries.

Country	% Change	Latitude
Norway	24%	63 N
Sweden	24%	60 N
Finland	21%	62 N
Iceland	19%	65 N

Source: Aase *et al.*, 1994: 130.

It is recognized that these countries have predominately fair skinned populations and different lifestyles, yet the rates of incidence have risen significantly in less than a 10 year period. This strengthens the link between ozone depletion, UVR and skin cancer and necessitates a close examination of Nunavut, as the latitude is comparable. Statistics Canada has compiled skin cancer data, and has described trends in the disease. The NWT has experienced an increase in skin cancer rates for males and a decrease for females. Between 1984 and 1993, all skin cancer incidences rose 32.9% for males and decreased 9.3% for females (Statistics Canada, 1996: 119).

Table 6 denotes the rates of MM per 100,000 people in the NWT from 1974-93.

Table 6. Rates of MM/100,000 in the NWT, 1974 to 1993.

Years	Male	Female
1974-1978	2.1	0
1979-1983	0	0
1984-1988	1.7	0
1988-1993	3	6.5

Source: Statistics Canada, 1996: 27.

Although there are lower incidences of MM, BCC and SCC at northern latitudes (50 degrees latitude and above) compared to mid and tropical latitudes, the incidence is rising thereby requiring greater attention from the scientific community.

Solar UVR can produce skin cancers, immune suppression and negative ocular effects in domestic and food animals (Intersun, 1995a: 5). No studies have been conducted on animals of the Arctic, such as the seal and caribou, staples of Inuit country foods.

The biological amplification factor (BAF) is the quantified measure of UVR reaching the ground, where: BAF = (d I / I) (d D /D)

dI = small increments in existing incidences of skin cancer
I = the existing rate of skin cancer
dD = small increments in existing biologically effective ambient levels of solar radiation
D = solar radiation (Armstrong, 1994: 879).

The BAF attempts to describe the percentage increase of skin cancer rates resulting from a 1% increase in the ambient UV irradiance reaching the ground. In studies conducted by Urbach (1989: 511), a 1% decrease in ozone is thought to lead to a 3% increase in non-melanomic skin cancer incidence. Moan *et al.*, (1989: 5211), in populations in Norway, found the following increases of specific cancers and UVR's BAF:

Table 7. Percentage Rates of Increase of Cancers from the BAF of UVR

Sex	BCC	SCC
Males	1.5 to 2.0	1.2 to 1.5
Females	1.6 to 2.1	1.6 to 1.8

Source: Moan *et al.*, 1989: 5211.

BCC and SCC were both found to have a higher rate of occurrance with a 1% decrease in ozone. Moan and Dalhback (1993), found increased rates of MM with a 1% decrease in ozone in Norway, Finland and Sweden displayed in Table 8.

Table 8. Percentage Increase of MM from BAF of UVR: Selected Nordic Countries

Country	Sex	BAF for Melanoma
Norway	Males	1.9
	Females	3.2
Finland	Males	1.3
	Females	2.2
Sweden	Males	1.9

Source: Moan and Dalhback, 1993.

These experiments assumed that the subjects involved resided their entire lives in the study area.

Biological effects of UVR are measured by erythemal dose. Erythema is the reddening of the skin caused by inflammation from the sun's burning rays. The inflammation results in vasodilatation, where blood vessels dilate, increasing blood flow to the surface of the skin (Wulf, 1994: 417). Different UV wavelengths may cause varying levels of erythema, known as the action spectrum. The action spectrum generally used is described by McKinlay and Diffey (1987: 17), and with ozone depletion, the action spectrum shifts to shorter wavelengths. The potency of UVR falls 1000% with an action spectrum shift of 300nm to 325nm, and 10,000% fall when the spectrum shifts from 300nm to 400nm (Wulf, 1994: 417). The longer the UV wavelength, the less biological damage it is responsible for.

Erythema is measured by B-MED units. One unit is equal to the basic minimal erythemal dose (B-MED), which is the first perceptible redness in fair-skinned persons: 0.312 kJ/m^2 at 296nm (Wulf, 1994: 418). Therefore, every nanometer the action spectrum is shifted shorter, due to ozone depletion, the biological effectiveness of that wave increases 15%, "indicating that only small changes in the ozone may have considerable biological consequences" (Wulf, 1994: 418). For example, a 5nm wavelength shortening shift would double the biologically active radiation (BAR), and a 7 nm shift would triple potential biological damage (Wulf, 1994: 418). Measurements were based on studies conducted on Caucasian subjects. It is very difficult to extrapolate this data with regard to effects of UVR on Inuit.

The probability of developing skin cancer falls along a continuum between environmental factors and a person's genetic make-up. Risk factors that increase the probability of developing skin cancer are: age, race (skin colour/protection factors), ethnicity group (social patterns, i.e. living outdoors), family history, general health, environment of habitation and occupation (Rinzler, 1991: 146). A person with fair skin, hair, and eye colour is more likely to develop skin cancer than a darker skinned person. Males and females share the same risks, however, men are traditionally twice as likely to die from skin cancers (Rinzler, 1991: 146). This may be due to increased exposure in traditional male roles of occupation or recreation which have lead to higher levels of UVR exposure.

3.4 Ultra Violet Radiation and Health Effects

Ultra violet radiation has been linked to the development of detrimental health

Figure 11. The strength of evidence linking UVR to health effects.

Nature of effect	Direction of effect	Strength of evidence for effect
Effect on immunity and infection		
Suppression of cell mediated immunity	Harmful (?)	Sufficient
Increased susceptibility to infection	Harmful	Inadequate
Impairment of prophylactic immunization	Harmful	Inadequate
Activation of latent virus infections	Harmful	Inadequate
Effects on the eye		
Acute photokeratitis and photoconjunctivitis	Harmful	Sufficient
Climatic droplet keratopathy	Harmful	Limited
Pterygium	Harmful	Limited
Cancer of the conjunctiva	Harmful	Inadequate
Lens opacity (cataract)	Harmful	Limited
Uveal melanoma	Harmful	Limited
Acute solar retinopathy	Harmful	Sufficient (?)
Macular degeneration	Harmful	Inadequate
Effects on the skin		
Malignant melanoma	Harmful	Sufficient
Non-melanocytic skin cancer	Harmful	Sufficient
Sunburn	Harmful	Sufficient
Chronic sun damage	Harmful	Variable
Photodermatoses	Harmful	Sufficient
Other direct effects		
Vitamin D production	Beneficial	Sufficient
Other cancers	Beneficial	Inadequate
General well-being	Beneficial	Inadequate
Indirect effects		
Effects on climate, food supply, disease vectors, atmospheric chemistry, etc.	Probably harmful	Inadequate

Source: taken from Armstrong, 1994: 874.

effects, where skin type, race or colour are irrelevant (Armstrong, 1994: 873). Figure 11 lists strengths of evidence links of UVR to various health effects.

UVR and the immune system

Clinically significant experiments in controlled trials, have linked UVR (UV-B) with the weakening of the immune system (Armstrong, 1994: 873; Environment Canada, 1997: 93; Garssen and Goettsch, 1996: 269; Jeevan *et al.*, 1994), specifically for the appearance of the herpes simplex virus, HIV, meningitis, skin cancer reoccurrence, and small pox lesions after UV irradiance. Elimination of certain necessary bacteria from lymph tissue, delayed hypersensitivity response to mycobacterial antigens, contact allergy reactions to chemicals and increased severity of infections. Testing in humans (as with animals) is still in early stages, however, thus far UV irradiance in clinical trials has lead to impaired contact allergy responses (Jeevan *et al.*, 1994; Saunder, 1992: 27).

Low UVR exposure suppresses the immune system at site, where high doses affect the entire immune system (Saunder, 1992: 27). UVR also affects the skin's natural immune surveillance functions, monitoring malignancies, cytokine pathways (immune system communication), and Langerhan's cells (infection fighters), and may down regulate immune system responses (Saunder, 1992: 27). It is believed that not only UV-B, but also UV-A, is responsible for this decrease in immune system responsiveness (Serre *et al.*, 1997: 187).

UVR and the skin

The skin is the first line of defense for the human body, protecting it from infections. It is the largest organ, covering an average area of 1.5 square metres in adults (Intersun, 1995b: 6). Skin can be grouped into three levels of pigmentation: 1) lightly pigmented: UVR will cause erythema, little tanning will occur, and generally the person is fair skinned; 2) intermediately pigmented: UVR causes little sunburn and always tans (i.e.) Mediterranean or Asian persons; 3) heavily pigmented: rarely sunburns (i.e.) African or

East Indian persons. These individuals have a lower probability of skin cancer, yet are susceptible to eye damage and immunosuppression (Intersun, 1995b: 7).

All major problems that involve the skin begin as minor problems from short term and long term UVR exposure. Minor short term UVR exposure to the skin may produce erythema, tanning, thickening of the epidermis (from UVB) and photosensitivity (depending on diet, medication and genetic make-up) (Intersun, 1995b: 7). Long term exposure to UVR may produce the following minor problems: dryness (as skin thickens and loses moisture), blemishes (breakage of small blood vessels), ageing (damaging of the elastin, collagen fibres, resulting in a loss of skin elasticity - (UVA mainly responsible)), and solar keratosis, a pre-cancerous multi-variant growth that is common on body sites with high levels of exposure (Intersun, 1995b: 8).

Sun damage is largely dependent on a number of variable factors: a person's sunburn history, wrinkling, and other manifestations of photo-ageing, such as, hyper/hypo-photosensitivity and degree of pigmentation and telangiectasia (thin, wrinkled atrophic skin) (Weinstock, 1992: 14). In terms of skin types and UVR risk, fairness of skin, hair, and eye colour are also determinant. The timing of exposure to solar UVR, in childhood or as a teenager versus adulthood, is very important, as early exposure in life to UVR is associated with malignant melanoma in sun-sensitive individuals (Weinstock, 1992: 14). As with skin cancer, there is uncertainty regarding causes for sun-induced skin disorders, yet there is ample evidence that UVR is one causal factor (Weinstock, 1992: 14). Long term regular outdoor exposure produces increased doses of UVR; this produces a lower risk factor than a subject who receives little regular exposure, but high doses of UVR from intermittent exposure from recreational activities (Elwood, 1992: 17).

There are a number of non-cancerous disorders involving the skin that have been linked to sun exposure and UVR. Actinic prurigo is a photosensitive disorder that is found in North American Natives, including the Inuit. It is most frequent in Native populations in Saskatchewan and Manitoba, and symptoms include reactions of the skin, at times severe, which may be accompanied by ocular problems and severe inflammation of the lower lip (Hogan, 1992: 23). Dermatomyositis is another inflammatory disorder in the skin and muscles, that is severely aggravated by UVR (Hogan, 1992: 23). Other disorders include atopic dematitus, acne, roacea and psoriasis.

UVR and skin damage in Inuit has scarcely been investigated; there have been no studies on solar keratosis, nor any pigmentation lesions registered from the Arctic (IASC, 1995: 13). One study was conducted on the Inuit by Wulf (1994), measuring skin pigmentation factors, comparing skin types to populations from Denmark and Scotland. The experiment measured previously unexposed buttocks (nates), considered a basic measure of sensitivity, and then other sites which received higher doses of UVR exposure.

Table 9. Susceptibility of Populations and Body Parts to UVR Exposure (the pigmentation protection factor)

Country	number		Protection	Factors	
		nate	forehead	back	breast
Scotland	29	1.2	2.1	1.6	1.8
Denmark	34	1.7	2.1	2.3	2.1
Inuit	30	2.5	2.9	3.1	2.4

Source: IASC, 1995: 13.

The constitutive pigmentation of the buttocks is 47% higher among the Inuit than in the Danish population (IASC, 1995: 13). On the back, the Inuit have a 30% higher level of protection than the Danes (IASC, 1995: 13). Immune suppression is believed to be independent of skin pigmentation (Noonan and Hoffman, 1994). Tanning and thickening of the skin are UV defences. When these defences are exhausted by increased UVR, damage that may occur to Inuit skin is unknown (IASC, 1995: 13).

The Inuit are prone to abnormal reactions to sunlight, known as polymorphic light eruptions (Wulf, pp.420, 1994). These reactions occur most frequently in spring, and appear as papular rashes, which disappear when sunlight is avoided. A study in Greenland surveyed 30 Inuit, of whom half claimed they experienced these rashes (Wulf, 1994: 420). It is not known if these rashes are exclusively caused by UV-A or UV-B. There are many factors associated with skin types and skin damage that must be incorporated into UVR studies on health.

UVR and the eye

The eye is sensitive to UVR and is affected negatively when UVR is absorbed. In the retinal layers and optic nerve, there may be the occurrence of MM (Grin *et al.*, 1998: 718). Geographical factors, specifically albedo from snow and ice, are important variables in terms of damage to the eye from UVR exposure. When snow and ice are the predominant ground cover, UVR is absorbed by the eye from direct sunlight, and also from the reflected or scattered light from below. UVR scatters very readily, so readily that even shade may not offer protection in the presence of a highly reflective surface, such as snow (Intersun, 1995b). Snow in Nunavut lasts into the months of summer, where there is prolonged hours of sunlight. Longer periods of UVR exposure, coupled with the highest levels of ozone depletion, results in a high risk period of time for UVR exposure to the eye. There are several disorders with suspected links to UVR, which, may develop in the eye (Armstrong, 1994: 877; Intersun, 1995b: 10).

3.5 UVR and Geographical Factors

Geographical factors are important variables in the relationship of UVR and health. These factors include latitude, in relation to the solar zenith, atmospheric circulation patterns, and total hours of sunlight. Albedo and polar vortex are other variables that affect UVR and ozone.

UVR, latitude and atmospheric circulation

Some studies (Masback *et al.*, 1997: 276; Pedlow *et al.*, 1997) have illustrated significant rises in rates of MM at latitudes comparable to Nunavut. These studies were conducted on Caucasian populations. The Inuit may still have a higher degree of natural protection, but the stronger levels of UVR may increase incidences of skin cancer, eye problems, diseases and infections related to immune suppression.

Nunavut is situated in a cold climate with a low atmospheric water content, which generally results in slower biomolecular reactions (Bottenheim, 1993: 41). Airborne contaminants that travel to the Arctic have a longer life span due to the cold temperatures present. The Arctic is vulnerable as it is one tenth the size of tropical regions (Climate Institute, 1989: 11), where cold temperatures coupled with weak Arctic circulation patterns, combine to create an "atmospheric reservoir" of contaminants (Bottenheim, 1993: 41). The concentration of atmospheric contaminants transported to the Arctic is known as global distillation (Pearce, 1997: 25). An example of the global distillation affect has occurred with PCBs. The same process occurs with ozone depleting chemicals.

During the Arctic polar night (November to March), there are low stratospheric ozone mixing rates in conjunction with higher concentrations of ozone depleting chemicals, setting the stage for severe ozone depletion. A study conducted by Bottenheim (1993: 52), found that during the polar sunrise in April 1992, Alert suffered a drastic reduction of ozone in the upper atmosphere. This severe thinning lasted into May, resulting in much higher levels of UVR reaching the surface. West to east flowing air delivers heat to the Arctic. This air is transported quickly and irregularly at the mid-latitudes in relatively small quantities. These air masses are then transported to high latitudes along fairly well established storm tracks.

The polar vortex

The tropopause is located at a vertical height of 12 km, which varies depending on latitude and season, in the atmosphere, with a median temperature of -50 degrees Celsius (Schoeberl *et al.*, 1991: 46). An inversion in temperature occurs through the stratosphere to a height of 50 km, where the median temperature rises to -20 degrees Celsius (Schoelberl *et al.*, 1991: 46). These temperatures allow for the absorption of UVR by ozone. This absorption of UVR heats the stratosphere, but is balanced by infrared radiation emission (Schoeberl *et al.*, 1991: 46).

During the winter solstice in the Arctic, there is no UVR as there is no sunlight, and therefore no atmospheric heating. This leads to a colder stratosphere in the Arctic compared to mid-latitude stratospheric temperatures. A latitudinal pressure gradient develops between the pole and mid-latitude air masses (Schoeberl *et al.*, 1991: 48). A circumpolar belt of westerly winds develops: the polar vortex. Wind speeds can reach 100 meters/second in the upper atmosphere (Schoelberl *et al.*, 1991: 47). The vortex forms in the range of 20 to 30 km in altitude in the atmosphere. The vortex can only be dissolved by heat in winter, which maybe brought to the Arctic by planetary atmospheric waves of circulation that propagate upwards, created by the earth's rotation and mountain ranges in Asia and North America (Schoelberl *et al.*, 1991: 47).

In the cold of the vortex, polar stratospheric clouds (PSC) condense, which contain high levels of nitrogen allowing free chlorine radicals to circulate. The chlorine released destroys ozone in the stratosphere. The process in the Arctic is not as strong as in the Antarctic, but is present nonetheless and affects ozone and UVR levels (Schoelberl *et al.*, 1991: 48). The vortex varies from year to year, and even week to week. It is dependent on Rosby waves that are variant; strong waves result in decreased ozone, weak waves results in higher levels of ozone (Schoelberl *et al.*, 1991).

The vortex isolates stratospheric air over the polar region during the polar night. With ozone depleting chemicals concentrated within the vortex, a total loss of ozone occurs in that column of atmosphere, resulting in a 40% decrease of ozone over the entire Arctic (Schoelberl *et al.*, 1991: 51). Cold air at the poles leads to a downward flow of air. In the upper stratosphere, air moves down to fill the void of cold air moving out below it, carrying chemicals with it. This downward flow leads to a warming resultant from adiabatic compression. Downward flowing cold air creates a boundary with warmer rising air, creating the vortex, allowing the destruction of captive ozone. As spring and summer approach, the vortex weakens and disappears.

In 1992, a strong vortex formed over the Arctic and migrated around the pole. In January, average Arctic ozone was measured at 196 Dobson units (Taalas *et al.*, 1995: 418). A model of the atmosphere with a doubled carbon dioxide content, predicts a stabilized vortex that lasts into April, depleting ozone and increasing UV irradiance in the Arctic, a process described by Taalas *et al.* (1995: 424).

UVR and solar elevation

The intensity of UVB-R depends on the height of the sun in the sky, while UVA-R is less dependent on solar elevation (Intersun, 1995b: 3). At 60 degrees north latitude, the total UVB irradiance for January and February is less than one clear day's exposure in midsummer (Intersun, 1995b: 3). Sunlight and UVR pass through the atmosphere close to the horizon. Here UVR must pass through more atmosphere compared to higher solar zeniths, such as in the tropics. UVR intensities actually increase with latitude, as the atmosphere thins at the poles due to the coriolis effect of a spinning earth (Intersun, 1995b: 4). More and shorter wavelengths reach higher latitudes as there is less atmosphere to stop shorter electromagnetic waves (i.e UVB)(Intersun, 1995b: 4). In the Arctic summer, during the summer solstice at 66.5 degrees latitude and above, the sun does not set, resulting in 24 hours of UV irradiance, with a thinned ozone layer in a thinner atmosphere.

Inuit have the potential to be exposed to high levels of UVB for long periods of time, increasing with latitude, and nearing the summer solstice. These high levels of UVR exposure, compared to no exposure in the winter, may produce a great health risk in relation to skin cancer, eye damage and immune system suppression.

UVR and albedo

Albedo is defined as the:

> "percent of incident solar energy which a surface reflects: a function of texture, colour, wetness, angle of beam, which generally increases with a decrease in solar elevation. The highest values are for snow and ice" (Maxwell, 1981: 34).

Nunavut has low solar elevations for many days of the year when snow and ice are the dominate ground cover. October through May, the average albedo of ground cover is at least 60%, while during June, July, August and September, the albedo is 20%.

Table 10 illustrates the increase in reflected energy (albedo) from April to August in Nunavut. These values are compared to Toronto to illustrate the increased risk Nunavut faces in terms of albedo energy.

Table 10. Mean daily reflected solar radiation (MJ/m^2), Resolute and Toronto.

Location	April	May	June	July	August
Resolute	10.98	16.34	10.99	4.5	2.75
Toronto	3.32	3.92	4.49	4.51	3.7

Source: Atmospheric Environment Service, 1982: 7.

In the spring at high latitudes, clear skies and snow reflection increase UV exposure levels to that of summer UV levels at mid-latitudes (Intersun, 1995b: 4). Albedo is dependent on time of day, latitude, month of the year (solar elevation/zenith), total ozone and cloudiness (Krzeminska *et al.*, 1998: 291).

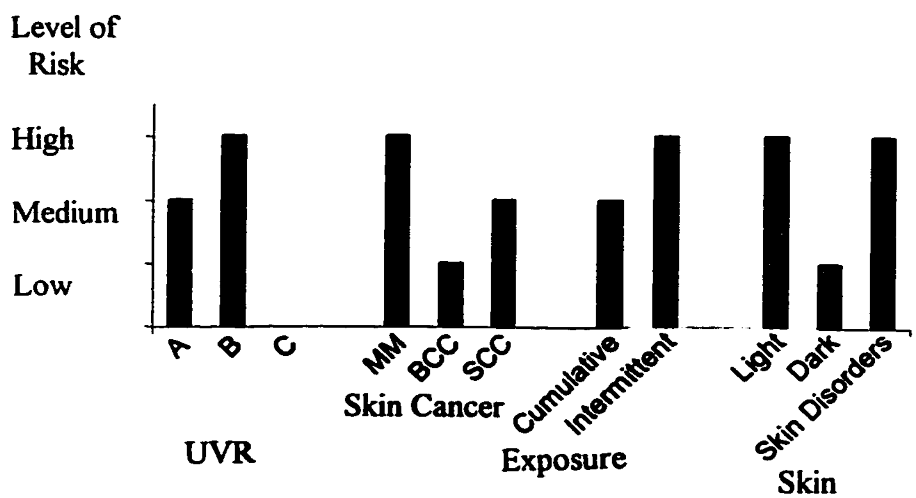
A study on snow, albedo and UVR in Finland (Jokela *et al.*, 1993: 559), at a latitude of 68.4 degrees north (roughly that of Igoolik and Hall Beach), reported degenerative effects on the cornea, ageing of the skin, cancer and erythema for Caucasian populations. Inuit skin type is darker, but this is not relevant for effects on the eye, erythema, and ageing of the skin, which occur within the Inuit population. With decreased levels of ozone "where maximum springtime values (of UV) are equal to midsummer doses of UV" due to albedo, risk is high and protection essential (Jokela *et al.*, 1993: 562).

Radiant energy is received and reflected very quickly and is strongest in late June at the summer solstice (Climate Institute, 1989). This coincides with when the Inuit leave settlements to camp, hunt, and return to the land. Snow reflection may account for 30%

of total radiation, which is diffuse radiation and very difficult to protect against, especially with the eyes (Wulf, 1994: 416).

Cataracts show latitudinal dependence at lower latitudes. However, for Arctic residents there is a very high albedo which would raise exposure levels. When UVR is at a wave frequency of 300 nm, 1% of the total UVR reaches the lens of the eye; at 290 nm, UVR is 250 times more potent than at 320 nm (Jones, 1989: 221). Age also increases UVR risk as the eye and its defences deteriorate. There is a strong link between UVR and cataracts in populations of Australian Aborigines, due to their lifestyle, time spent out of doors, and lack of eye protection against the sun (Jones, 1989: 221). There are no data kept regarding cataracts in the NWT (Corriveau, 1999).

Figure 12 Summary of presently known risk factors in Nunavut.

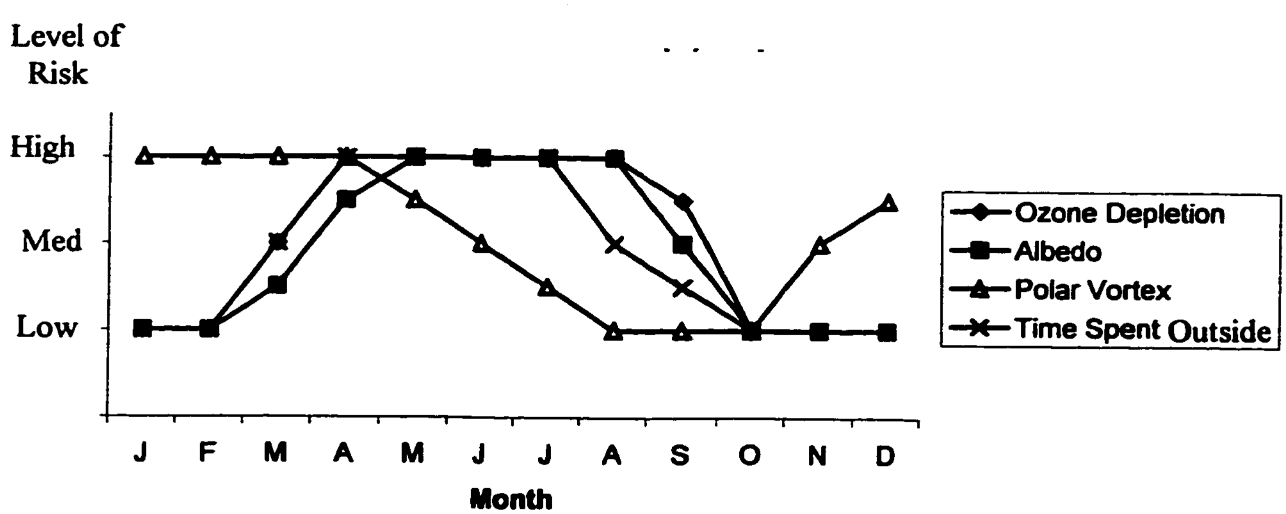


As a summary to this section, Figure 12 summarizes the degree of risk the Inuit may face in terms of factors of exposure, lifestyle and genetics. This graph illustrates the levels (high, medium, low) in Nunavut for various risk factors: the type of UVR, the type of skin cancer, the degree of exposure to UVR, type of skin colour, and the risk of having skin disorders. The levels of risk were determined from results of research reviewed in this section. In all health concerns, genetics play an important role. The development of these conditions may be heavily influenced by the environment of Nunavut, but a person's genetic make-up may play a large role in determining if these conditions become a threat.

UV-B is the greatest risk factor to the Inuit, as it is the most biologically damaging. MM is the most deadly form of skin cancer. It is believed to develop from strong intermittent UVR exposure. SCC and BCC are more easily treated; their development is thought to be influenced by cumulative UVR exposure. Populations with light coloured skin and history of skin disorders are at high risk, where darker skinned populations have more natural protection from UVR (in terms of skin cancer development).

Figure 13 illustrates a summary of physical risks of exposure per month of the year. Variables considered include ozone depletion, albedo, polar vortex and time spent

Figure 13 Summary of exposure risk factors.



on the land (relating to the "summer buzz" and the hunting of country foods). In the problem of UVR exposure and health in Nunavut, there is no one variable that poses a great threat. There are many factors that together pose a serious threat to health.

The polar vortex destroys most ozone between November to April. The risk occurs when the sun rises again and there is less ozone to absorb UVR. Albedo peaks in risk from March to August, as the sun is strongest and any remaining ice and snow reflect large percentages of UVR. The greatest risk from ozone depletion occurs when long periods of summer sunlight are present in Nunavut. Ozone depletion and time spent on the land share the same peak times in the year, resulting in great risk for Nunavut in terms of UVR exposure.

Factors which add to the risk, vulnerability and complexity of the problem include: a population that is sparsely populated, ill-informed of the dangers of UVR, increases recorded in sunburns and requests for sunscreen. The traditional culture of the Inuit is threatened, as time spent on the land is dangerous without UVR protection and education. As well, the country foods the Inuit rely on for food and culture may be seriously threatened by UVR exposure. Strategies from southern Canada are not applicable to Nunavut due to the differences in culture, population distribution and size of the territory. These summary graphs will be used in the analysis of this thesis. The next section will discuss the data and methods used in the analysis.

DATA SOURCES and METHODS

This section will discuss the data sources, their strengths and weaknesses. As there were only 5 reported cases of skin cancer from 1990 - 1997, a statistical analysis of the data is not possible. On the basis of data discussed in this section, emphasis will be placed on risk and vulnerability factors, as they pertain to scenario zones within Nunavut (analysis section). The logic behind collecting the data was to establish a thorough baseline of information that would lend evidence to support the hypothesis that as ozone depletion occurs over Nunavut, UVR penetration will increase and negative health effects could occur. These baseline data range from ozone loss and albedo percentages to more tangential factors such as occupation.

Little research has been undertaken regarding UVR and the above-mentioned negative health factors among the Inuit. As shown previously, some studies have been done on Caucasian populations in Nordic countries whose latitude is similar to the Canadian Arctic, but Inuit skin types greatly differ, making comparisons very hazardous. There are other problems specific to the use of northern data. Reporting of cancer cases is done federally or territorially, resulting in the potential for less accurate data (Corriveau, 1998). In most cases, cancer registries do not receive all data on NMSC, only patients admitted to hospitals have data passed on to registries (Decker, 1999). Also, MM cancer has a high potential to spread to other parts of the body and the primary cause of death may not be recorded as a MM. As well, physicians in northern regions tend to be itinerant and may not have known the client.

The majority of the data used in this study has been measured for the NWT as a whole. Nunavut was only established as a separate territory in April of 1999 and some government agencies consulted for this study are exhibiting various degrees of confusion as to their mandates.

The data used in this study were collected over various time frames: ozone and solar radiation hourly; skin cancers and occupational data yearly; latitude and solar zenith are constants; rural and urban population, perceptions on health and statistics directly related to the Inuit, such as percentage of time spent acquiring country foods, according to research demands. These differences make analyses of the data difficult.

4.1 Baseline Data

a) Anecdotal data

Anecdotal data came from e-mail and phone to northern researchers and administrators, and from interviews carried out by researchers. Fox (1998) conducted interviews with the Baffin Island Inuit on their perceptions of weather and climate and use of traditional knowledge. The Inuit's comments such as "a stinging sharper sun" and the "heat of the sun is sharper now" (Fox, 1998: 104), did not imply that the sun was hotter but that increases in UVR made the sun's rays feel stronger. These complaints were mirrored by increased frequencies of sunburns and requests for sunscreen lotions at medical stations, according to Fox.

Employees in government offices, such as the office of the Director of Medical Affairs for Nunavut, in Iqaluit, downplayed any UVR concerns. The Nunavut Social Services office houses all research and promotion programs for Nunavut. No UVR literature was present in this office. An employee of the Public Health Officer in Iqaluit, when interviewed, mentioned that there is an automated UV-index recording run by Environment Canada, from June until August. This system is an automated telephone line, accessible only by telephone. It was also indicated that the office recommends the wearing of sunglasses for protection against UVR (personal communication, Public Health Office, 1999).

The Nunavut Research Office in Iqaluit approves and aids in administering all research done on Baffin Island. One of the employees at this station, who had been there for 2 years, was unaware of the existence of a UV-index, and had neither seen nor heard of any type of UVR protection and prevention literature (Personal Communication, Nunavut Research Office, 1999).

For the Arctic region as a whole, the following comments solicited from researchers, scientists, and physicians whose work is related in one way or another to UVR and health effects, illustrate the gap awaiting to be filled on this subject:

- "Indeed, this area has virtually no research, at least none I am aware of."
  - Dr.Edward DeFabo, Washington University Medical Centre, 1999.
- "I...do not know of much research that specifically studies the effects of UV on Inuit health."
  - James Kerr, Atmospheric Environment Service (Canada), 1999.
- "I have no references to UVR and Inuit health other than what was in the International Arctic Science Committee."
  - Dr. Desmond Lugg, Head Polar Medicine, Australian Antarctic Div., 1999.
- "The Arctic Institute of North America has no researchers working on this subject and has published no books or reports on it."
  - Ross Goodwin, Arctic Institute of North America, University of Calgary, 1999.
- "There are very sparse information on health problems related to UV in the Arctic environment."
  - Dr. Hans Wulf, Department Head, Copenhagen University Hospital, 1999.
- "Unfortunately, I am unable to provide much of the information you request (UVR, Inuit's and health). With respect to skin cancer, the information is really sparse."
  - Dr. Hans Storm, Danish Cancer Society, 1999.
- "We are not aware of any programs in place or planned concerning UV exposure and health in the Arctic."
  - Shirley Fincham, PhD., Alberta Cancer Board, 1998.

These comments suggest no research is being done, perhaps because of general lack of awareness, or because the small number of cases among a population such as the Inuit, who have numerous other serious health issues (such as high rates of infectious disease and suicides), have not warranted UVR studies. It may also be simple lack of awareness of potential risks.

b) Physical geographical data

The following physical geographical data are an integral part of risk evaluation: latitudinal factors such as solar zenith, albedo and elevation; sunlight hours; and temperature. Latitude is arguably the most important geographic factor. Populations at various latitudes are differentially affected as geographical factors such as albedo, sunlight hours and solar zenith vary, as well as UVR levels. A common misconception regarding Nordic countries in high latitudes is that these countries receive low intensity radiation, resulting in lower risk, but in fact, Nordic cancer registries possess the highest sustained increase in skin cancer rates over time in the world (Aase and Bentham, 1994: 129).

Solar elevation, or zenith angle of the sun, is directly related to the scattering of UVR and therefore the BED of UVR. The lower the zenith angle, the more scattering of UVR will occur. Table 11 displays zenith angles for various latitudes from 45 degrees North (representative of Toronto, Ontario) to 90 degrees North (North Pole), and for the summer solstice (June 22nd) and the spring and autumn equinoxes (March 21st,

Table 11. Maximum minimum daily solar zenith values at north latitudes.

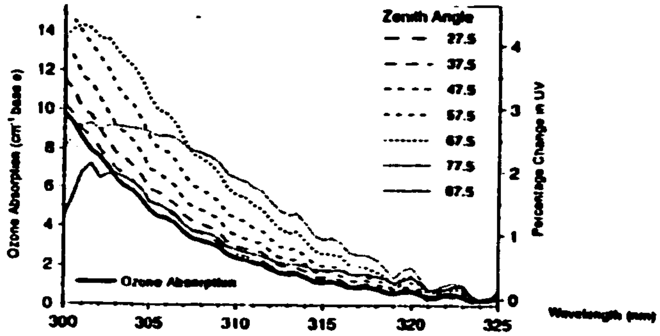
Latitude	June 22	Mar.21/Sept.23
90	24/24	0/0
80	33/13	10/0
70	44/4	20/0
65	49/0	25/0
45	69/0	45/0

Source: Maxwell, 1981: 7.

September 23rd). The Arctic zone, which encompasses most of Nunavut extends from 60 degrees North latitude to the pole. During the summer solstice in this zone, the sun does not set, resulting in 24 hours of irradiance. During the winter solstice in the high Arctic, there is no UVR irradiance as there is little sunlight.

Figure 14 illustrates the percent increase of UVR in relation to zenith angle, atmospheric ozone absorption, and UV wavelength. The shorter the UV wavelength, the greater the potential for biological damage, at all solar zeniths (Wardle *et al.*, 1997). In the summer solstice, most of Nunavut has a solar zenith of 47.5 degrees and less. With ozone depletion, there is less absorption of UVR, and even though the solar angle is low in the Arctic, more UVR is reaching the surface for extended periods during the 24 hours of light. Health risks may be influenced by the zenith angle and corresponding UVR. Zenith angle differences may equate to seemingly small fluxes in UVR penetration, however a 1% UVR increase can have large effects on BAF and BED, making zenith angles significant factors in UVR exposure.

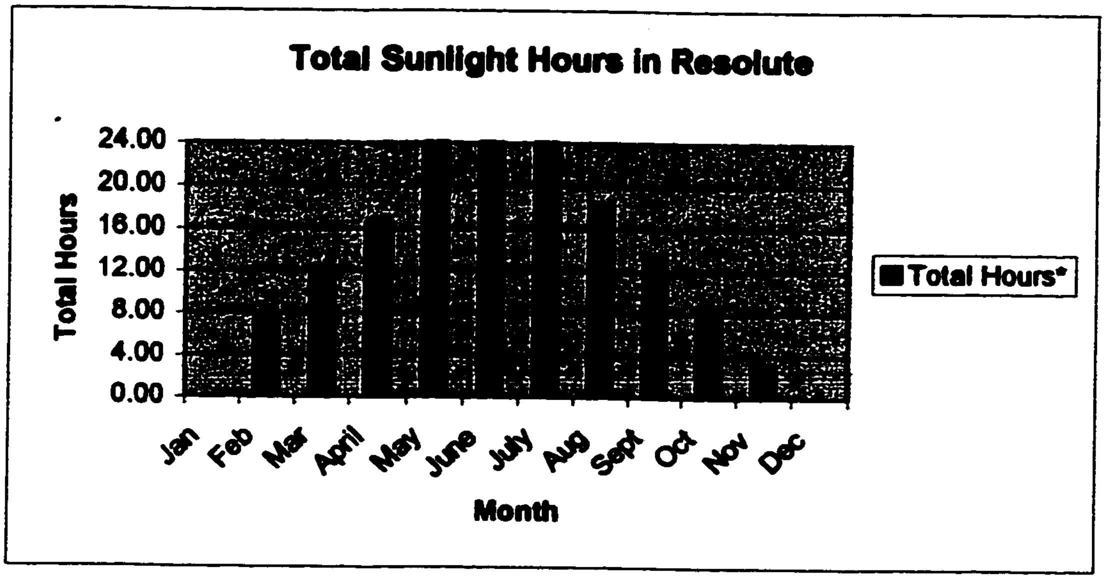
Figure 14. Sensitivity of UV irradiance to total ozone per 1% change in total ozone as a function of wavelength for different zenith angles.

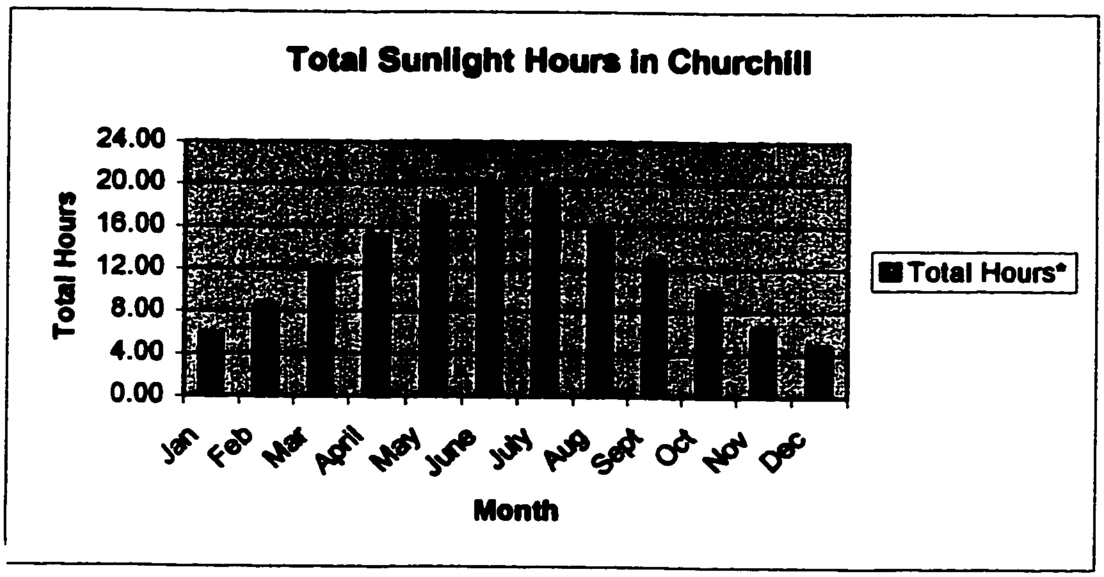


Source: taken from Wardle *et al.*, 1997: 75.

The potency of cumulative hours of sunlight and UVR are partially dependent on solar zenith and albedo. Figure 15 indicates sunlight hours for Resolute and Churchill. Resolute, at 76 degrees North latitude has 3 months where the sun shines for 24 hours (May to July). In Churchill, at 58 degrees North latitude, the peak of sunlight hours occurs in June (22 hours). This poses a greater threat of exposure that is resultant from higher latitudes.

Figure 15. Total sunlight hours in Resolute (74 N) and Churchill (58 N).





Source: Energy, Mines and Resources Canada, Map, 1983.

Table 12 displays the mean daily global solar radiation recorded at Alert, Resolute and Iqaluit in MJ/m^2. In April and August, solar radiation MJ/m^2 increases as latitude decreases, but in May, June and July, total solar radiation is lower at the lower altitudes. Again, through May to July, Northern latitudes have higher levels of solar radiation than lower latitudes. This results in higher risk from UVR.

Table 12. Daily mean global solar radiation MJ/m^2.

Station	April	May	June	July	August
Alert 82 N	11.8	23.1	24.5	18.4	10.1
Resolute 76 N	14.9	23.7	25.1	17.9	11.3
Iqaluit 63 N	18.2	20.1	17.9	16.1	12

Source: McKay and Morris, 1985: B-1.

Though temperature is not directly related to UVR and health effects, it is a useful variable to consider in summer months; less clothing is worn if temperatures are higher, offering less protection from UVR. For Alert, Resolute and Iqaluit, the average daily temperatures are shown is Table 13. Although temperatures reach higher values at southern latitudes, there is a greater increase in temperature in the north, in Alert (-21.3 to 6.1 degrees Celsius from April to July, a 27 degree change) compared to Iqaluit (-10 to 11.6 degrees Celsius from April to July, a 22 degree change). If one is acclimatized to extremely cold temperatures, the increase in temperature in Alert may warrant the wearing of much less clothing, possibly increasing exposure.

Table 13. Mean maximum daily temperatures, 1961 to 1990, degrees Celsius.

Location	April	May	June	July	August
Alert 82 N	-21.3	-8.7	.1.3	6.1	3.6
Resolute 76 N	-19.9	-7.9	1.6	6.8	4.3
Iqaluit 63 N	-9.9	-0.7	6.5	11.6	10.2

Source: Environment Canada, 1993: 15.

c) Human geographical and health-related data

There are limited skin cancer statistics available. There are no data in Nunavut on cataracts, and immunosuppressive problems are not easily diagnosed nor categorized (Corriveau, 1999). Table 14 indicates the number of cases of NMSC (ICD-9, 173.0-173.9) from districts within Nunavut.

Table 14. Non-melanomic skin cancer cases, 1990 to 1997, Nunavut.

Year	Baffin	Keewatin	Kitikemeot	Nunavut Total
1990	1	0	0	1
1991	1	0	0	1
1992	0	0	0	0
1993	0	0	1	1
1994	0	0	0	0
1995	0	0	1	1
1996	0	0	0	0
1997	1	0	0	1
Total	*3*	*0*	*2*	*5*

Source: Corriveau, NWT Health Protection Unit, 1998.

There is no pattern of increasing or decreasing cases over time and no clear clustering of cases in any region. Increased rates of skin cancer in the Arctic are not expected for several years until cumulative exposure to increasing rates of UVR has taken effect. According to Miller and Gaudette (1996: 607), "UVR has not had an effect yet"; 35 cases were reported between 1969 and 1988 among the Inuit in the circumpolar north as a whole, but this number is expected to increase by 2010 (Miller *et al.*, 1996: 615) as cancer lag times catch up to exposure rates. Also, from 1969 to 1988, 8 cases of MM skin cancer were reported in the circumpolar region (Miller *et al.*, 1996: 607). Corriveau (personal communication, 1999), reported 1 case of MM skin cancer in the Keewatin district between 1990 and 1997. In conclusion, there are more cases of NMSC being reported than MM skin cancer, and it is unclear what constitutes true incidence, or real increases in the number of cases as opposed to diagnosis and the reporting of cases.

Rural populations may be at higher risk to UVR exposure than urban residents, because they tend to work out-of-doors in procuring country foods and living off the land, being exposed to more of both intermittent and cumulative UVR. The average Arctic labour force in Canada is approximately 10,000 people. Fifty-seven percent of this workforce is categorized as 'other', defined as categories that possess less than 0.5% of the workforce, non-specific responses, or responses that did not fit into industrial categories. This 'other' category may correspond to the moderately high percent of rural people whose occupation is living off the land. Table 15 denotes the rural-urban breakdown of regions within Nunavut.

Table 15. Urban/rural breakdown for Nunavut.

Region	pop'n Urban	pop'n Rural	% Rural
Baffin	5161	8057	61%
Keewatin	2058	4810	70%
Kitikmeot	0	4626	100%
Nunavut	*7219*	*17493*	*71%*

Source: Statistics Canada, 1997: 158.

Overall, 71% of Nunavut's population resides in rural areas, but in Baffin, which has 13 communities varying in size from a few hundred to over 4,000 people in its capital, Iqaluit, only 61% live off the land. The highest risk region is Kitikmeot, where 100% of the people live in rural areas. In conclusion, there are also differences within regions, which make it difficult to assign risk levels.

4.2 Scenario Zones

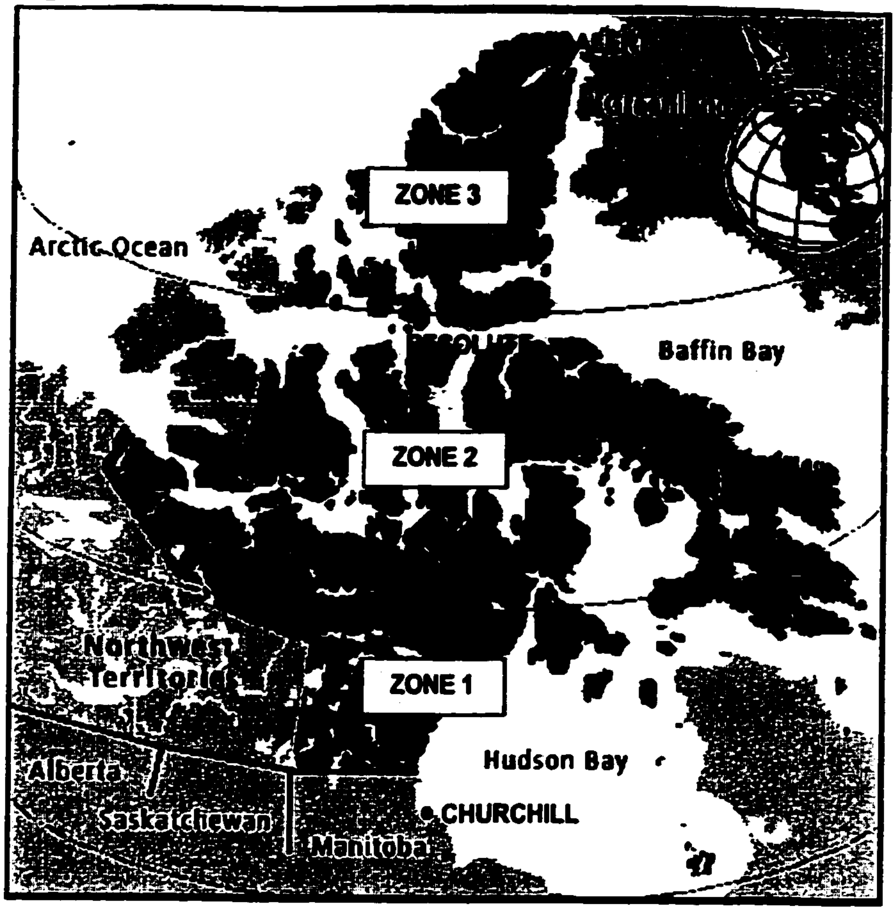
From the literature, it has been established that behaviour, genetics and the environment one inhabits, are major determinants in the link between UVR and detrimental health effects. Figure 12 and 13 summarized the degrees of risk which the Inuit face from factors implicated with UVR. To analyze risk and vulnerability factors, Figure 16 divides Nunavut into 3 sections based on latitude and population size.

Zone 1: 56.5 degrees, Sanikiluq in Southern Hudson's Bay to 65 degrees. Encompasses 10 communities and a population of 12,675. (Southern Nunavut)

Zone 2: 65 to 75 degrees, from Pangnitung to Resolute. Encompasses 16 communities and a population of 11, 586. (Middle Nunavut)

Zone 3: 75 degrees to the north pole, includes the communities of Grise Fiord and Alert, a population of 148. (High Nunavut)

Figure 16. Nunavut risk scenario zones



Source: base map taken from www.nunavut.com

As has been shown, latitude is an important variable in UVR considerations, as the entire territory of Nunavut covers more than 30 degrees of latitude. The establishment of these zones will minimize generalizations regarding health effects from UVR and assist the health departments in making more location-specific decisions on how to deal with the problems of UVR health effects. These high (zone 3), mid and low zones of roughly 10 degrees of latitude each, are described below. Each zone has a latitudinal border, but individual risks and vulnerability are variable; borders for the zones are not rigid, merely guidelines to analyze a general area according to the variables. Each zone had one community large enough to possess data.

Zone 1, Southern Nunavut, has data from Churchill (58 degrees north). In certain instances data were collected from Iqaluit (64 degrees north) (mean daily solar radiation, maximum mean daily temperature) when data were not available from Churchill. Zone 2, Middle Nunavut, had data collected from Resolute (74 degrees north). These data are from the northern limit of Zone 2. Zone 3, High Nunavut, had data from Alert (85 degrees north). The zones are divided according to the number of communities, population, and availability of data.

The rationale behind this division is based on problems and difficulties faced when dealing with data from Nunavut regarding UVR and health. Most data deal with the NWT instead of Nunavut. Nunavut is also divided into 3 districts, Baffin, Keewatin, and Kitikmeot. These political divisions are more longitudinally orientated, whereas variables in this study are latitudinally orientated.

Data for the 3 scenario zones are summarized in Table 16. The data used in analyzing the scenario zones in Nunavut (Table 16) were divided into 6 basic groupings.

1. Ozone data: ozone data was collected from Alert, Resolute, and Churchill Manitoba.
- From ozone data, the % increase or decrease in the following variables were calculated: ozone, UVR, ground level UVB flux, and the Biological Amplification Dosage (BAD).

2. Solar zenith: the minimum and maximum angles of the sun at latitudes for zones 1, 2, and 3.

3. Solar zenith angle of the sun in conjunction with effects of a 1% decrease in total ozone: illustrates the solar angle per zone, the decrease in ozone absorption, and the increase in UVR penetration.

4. Albedo: albedo values for each zone for spring, summer and autumn.

5. Sunlight hours per representative community per zone: hours of light from April to September, along with the daily mean for solar radiation (MJ), from April to September.

Table 16. Nunavut latitudinal zone scenarios

Variable:	**Southern Nunavut** 56 to 65 degrees, 10 communities, 12,675 people, Churchill 56 degrees		**Middle Nunavut** 65 to 75 degrees, 16 communities, 11,586 people, Resolute 74 degrees		**High Nunavut** 75 degrees to pole, 2 communities 148 people, Alert 85 degrees	
Ozone	year	O_3(DU)	year	O_3(DU)	year	O_3(DU)
	1987	362	1960/65/70	388	pre 1970	364
	1988	355	1987	375	1987	n/a
	1989	356	1988	382	1988	399
	1990	340	1989	375	1989	342
	1991	362	1990	372	1990	358
	1992	360	1991	375	1991	369
	1993	345	1992	378	1992	338
	1994	362	1993	345	1993	320
	1995	n/a	1994	368	1994	345 (apr.-sept.)
	1996	336	1995	354	1995	n/a (june-sept.)
O_3 loss % ('79-92)	-8%		-8.5%		-9%	
UVR % increase (79-92)	+13%		+14.5%		+15%	
UVB ground flux	+4%		+4%		+4.5%	
BAD	+16%		+17%		+18%	

Solar zenith angles: (min/max) on June 22

	Southern Nunavut	Middle Nunavut	High Nunavut
	@ 65 degrees (d.) (49/0)	@ 70 d. (44/4)	@80 d. (33/13) @90 d. (24/24)

Zenith angle with a 1% reduction in total ozone (a=angle, ab=ozone absorption, uvr=uvr % increase)

	Southern Nunavut	Middle Nunavut	High Nunavut
	a=47.5 ab= -7% uvr= +1.9%	a=37.5 ab= -6% uvr= +1.5%	a=27.5 ab= -5% uvr= +1.4%

Albedo (w=winter, s=spring, su=summer, f=autumn, mo=months)

	Southern Nunavut	Middle Nunavut	High Nunavut
	w(6 mo) = >80%	w(6 - 8 mo) = >80%	w(>8 mo) = 80%
	s(2 mo) = 60 - 80 %	s(1 mo) = 60 - 80%	s(1 mo) = 60 - 80%
	su(3 mo) = 20%	su(2 mo) = 20%	su(1 mo) = 20%
	f(1 mo) = <20%	f(1 mo) = <20%	

Sunlight hours (April, May, June, July, August, September)

	A	M	J	J	A	S
Southern Nunavut	14.5	18	20	19	16	12.5
Middle Nunavut	16.5	24	24	24	18.5	13.5
High Nunavut	20	24	24	24	24	20

Mean daily solar radiation (MJ/m^2) (values for Southern Nunavut recorded in Iqaluit)

	A	M	J	J	A
Southern Nunavut	18	20	18	16	12
Middle Nunavut	15	24	25	18	11
High Nunavut	12	23	25	18	10

Maximum mean daily temperature 1961 - 1990 (degrees Celcius) (April, May, June, July, August)
(values for Southern Nunavut recorded in Iqaluit)

	A	M	J	J	A
Southern Nunavut	-10	-1	7	12	10
Middle Nunavut	-20	-8	2	7	4
High Nunavut	-21	-9	1	6	4

6. Temperature: the mean daily maximum (1961 to 1990) for each zone's representative community from April to August.

Certain variables had values measured in months (temperature, sunlight hours, solar radiation). Only the months from April to August or September were displayed and analyzed, as the months not included have very low levels of sunlight and therefore UVR.

Table 17 displays the non-latitudinally related data used. In the analysis, this data will aid in illustrating the vulnerability of the people of Nunavut. The four variables used were: perception of health care, hospital beds per capita, rural percentage of the population and division of the labour force. The perception of health care was measured on a territorial and Canadian level. These variables may be less significant, but still have

Table 17. Non-latitudinal data for Nunavut scenario zones.

Perception of health care (% in agreement)

Perception	Native (NWT)	Non-Native (NWT)	Provincial
excellent or good	47	75	63
fair or poor	12	6	10

Hospital beds per capita

Nunavut	1 / 235
Baffin	1 / 200
Keewatin	1 / 286
Kitikmeot	1 / 308

Rural percentage of the population

Nunavut	71 %
Baffin	61%
Keewatin	70%
Kitikmeot	100%

Labour force division (NWT)

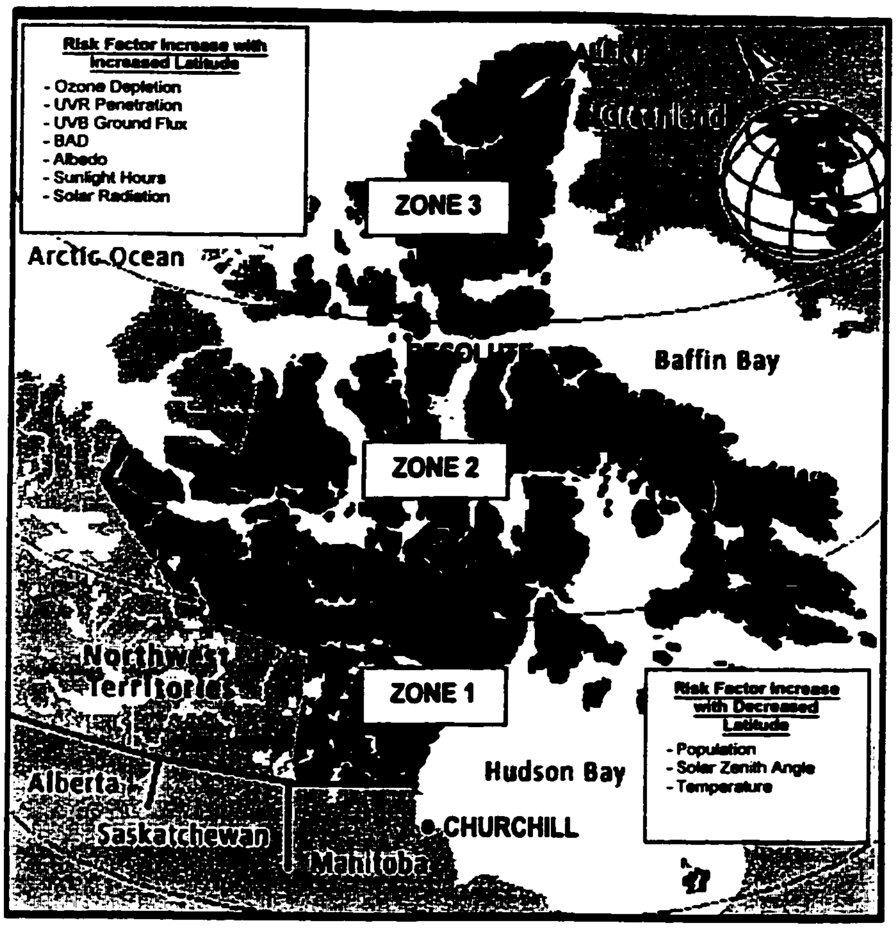
services	29.1%
construction	5.1%
transportation or storage	4.5%
mining	2.5%
manufacturing	1.5%
other (hunting, trapping, non-defined)	57.3%

value in displaying differences from southern Canada and the Arctic, further illustrating Nunavut's uniqueness. Hospital beds per person (measured as per political divisions), coupled with the rural population breakdown, shows rural populations may have a lower level of accessibility to health care (Kitikmeot) compared to more urbanized regions (Baffin). Rural population percentages were measured according to the political divisions of Nunavut and also demonstrate vulnerability in the population, as rural populations may have lower accessibility to health care. These variables will be analyzed and discussed in the following section.

ANALYSIS AND DISCUSSION

This section of the thesis will analyze and discuss the variables chosen for inclusion in the scenario zones over Nunavut (Table 16), and examine risk factors leading to vulnerabilities of the population of Nunavut. For each of the three zones, two graphs have been created. The first graph for each zone will illustrate factors of risk (Figures 18, 20, 22), while the second set of graphs illustrates vulnerability of exposure. The analysis will be based on UV-B radiation as it has the highest potential for harm due to its shorter wavelength. As well, due to the coriolis effect and ozone depletion, greater levels of shorter wave UVR penetrate the atmosphere. UV-A is of less risk even though evidence is building linking it to skin cancer development.

Figure 17. Nunavut latitudinal scenario zones with risk factors.



Source: Base map taken from, http://www.nunavut.com.

Figure 17 depicts the three zones of Nunavut and factors that increase or decrease risk as you move through the zones. As a general statement, overall risk is similar throughout Nunavut. Specific risk factors, however, are more important to health as latitude changes and will be helpful in educating the public of their vulnerabilities in relation to location.

Factors which increase risk of damage from UVR moving south from Zone 3 to Zone 1 include:

a) population density and population types
b) solar zenith angle
c) temperature

Population density increases moving south, as well the probability of having more cases of UVR related health effects reported increases. Fairer-skinned Caucasians who predominate the southern latitudes have a higher probability of acquiring damage from UVR in the form of skin cancers. They are also more likely to wear less clothing in hotter climates, increasing their risk of exposure to UVR. The solar angle is higher in the south which increases the strength of the sun for periods during the day and thus increases risk.

Factors which increase risk of damage from UVR moving north from Zone 1 through to Zone 3 include:

a) ozone depletion
b) UVR penetration
c) UV-B ground flux
d) BAD
e) albedo
f) sunlight hours
g) solar radiation

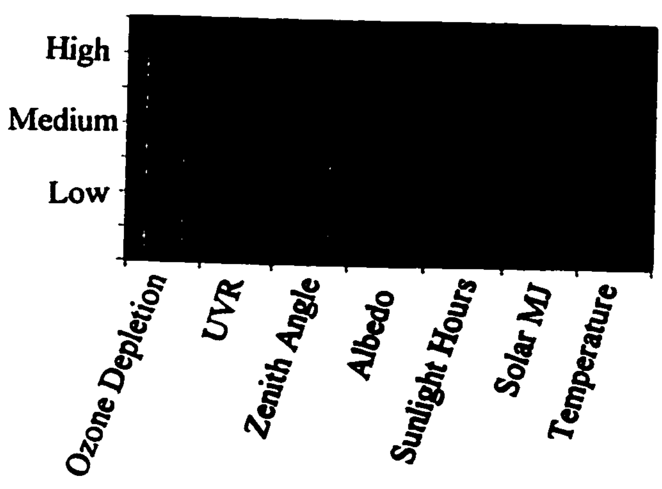
From Zone 1 to 3, total ozone depletion ranges from 8 % to 9%, a small but significant increase when measurements such as BAD are included. BAD increases from 16 % in Zone 1 to 18 % in Zone 3. UVR penetration increases from 13 % to 15 % and UV-B ground flux increases from 4 % to 4.5 %. A 1 % increase in UVR may increase

RAF rates: for MM skin cancer, a 2% increase; for non-MM skin cancer, a 2 % to 3 % increase; for cataracts, a 1 % to 2 % increase; and for immunosuppression, a 1 % to 2 % increase. With a 14% increase in UVR in Nunavut, the RAF for MM (2%) should result in a 28% increase in MM. This is not the case and may be resultant from lower temperatures and therefore more clothing worn. Even though the solar zenith angle is low, long periods of sunlight increase the total MJs of energy from the sun at the surface in higher latitudes. At the surface, more snow and ice remain for longer periods, which increases the albedo effect. This effect remains into the summer months of long sunlight hours and warmer temperatures and remains a high risk time.

Figure 18 displays factors of risk for Zone 1. Ozone depletion is lowest in this zone, and the difference is 1% from Zone 3. Increased UVR penetration is less of a risk independently, however, higher zenith angles occur in southern Nunavut and combined with higher temperatures, raise the risk of exposure. Sunlight hours and MJ energy are lowest in Zone 1, as well as albedo, therefore these risks have been assigned a medium and low rating respectively.

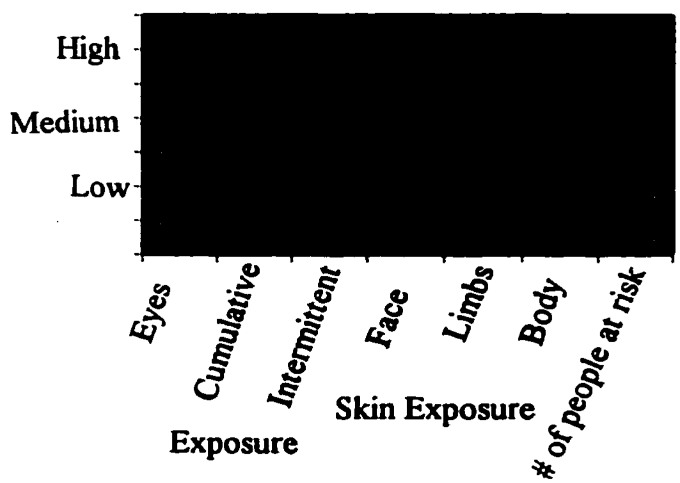
Figure 19 illustrates the factors of vulnerability in Zone 1. As there is a lower albedo, risk for eye damage is lowered, however, with a higher zenith angle, UVR has less

Figure 18. Factors of risk: Zone 1



atmosphere to penetrate to reach the eyes, resulting in a medium risk to the eyes. Cumulative exposure and intermittent exposure both have a medium risk ratings as (comparatively) sunlight hours are less (on average 17.5 hours). However, there still is a risk from prolonged summer sunshine. Intermittent exposure is also rated as medium as the zenith angle is higher producing stronger rays. In terms of skin exposure, the face is exposed, but is at a lower vulnerability compared to other zones as there is less albedo.

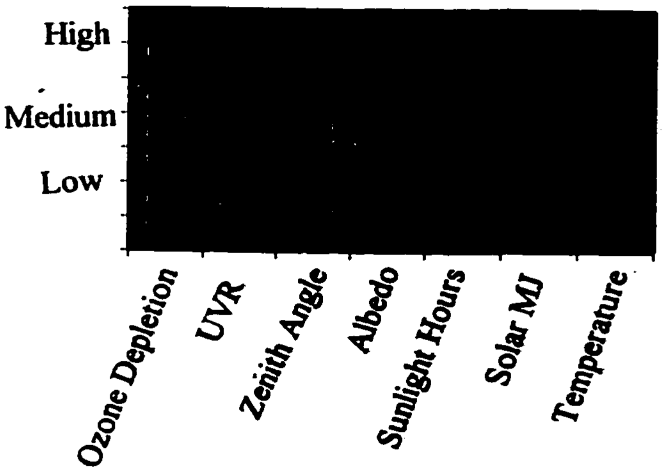
Figure 19. Factors of vulnerability: Zone 1.



Limbs on the body have a high vulnerability rating, as the July average temperature in Zone 1 reaches 12 degrees Celsius, resulting in less clothing worn, as it is not known whether the vast temperature changes that occur in Zone 2 and Zone 3 (from -20s to 5 or 6 degrees) result in greater exposure. The vulnerability to the rest of the body remains low.

The risk factors in Zone 2 are a mixture of those faced in Zones 1 and 3 (Figure 20). The differences from Zone 1 include the zenith angle, with a lower maximum, therefore producing less risk and being assigned a medium rating. Albedo becomes a greater factor moving north as temperatures stay lower, leaving snow and ice on the ground longer. Albedo has a medium risk rating, where as sunlight hours (average 21.4) and solar radiation (MJ) have high risk ratings. Solar energy (MJ) reaching the surface is

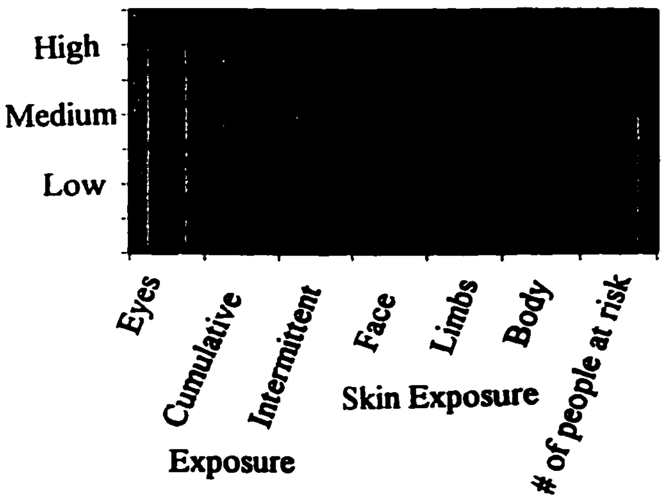
Figure 20. Factors of risk: Zone 2.



highest in this zone. Sunlight hours and energy in conjunction with temperature (July average: 7 degrees Celsius) produce a medium risk measure for temperature.

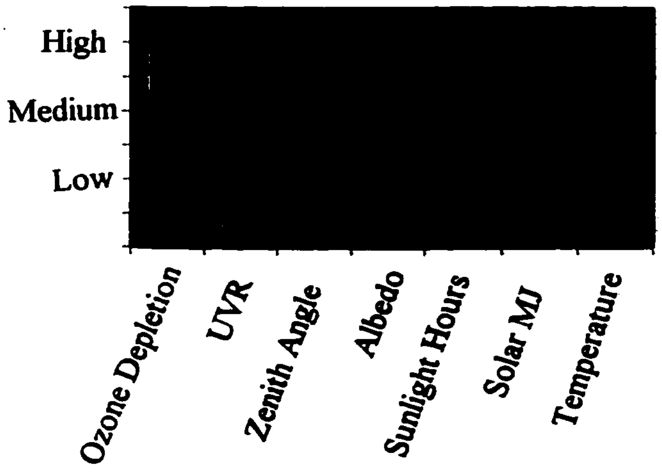
Figure 21 illustrates vulnerability in Zone 2. The eyes become more vulnerable with a greater albedo and longer sunlight hours, even though there is a lower zenith angle. Cumulative exposure is high in Zone 2, and intermittent exposure remains at a medium level as once again, there are long sunlight hours. Vulnerability of the face to UVR is high

Figure 21. Factors of vulnerability: Zone 2.



(due to albedo, sunlight hours, cumulative exposure), but to the limbs and rest of the body are low as the threat of high temperatures to prolong exposure to these areas is low.

Figure 22. Factors of risk: Zone 3.

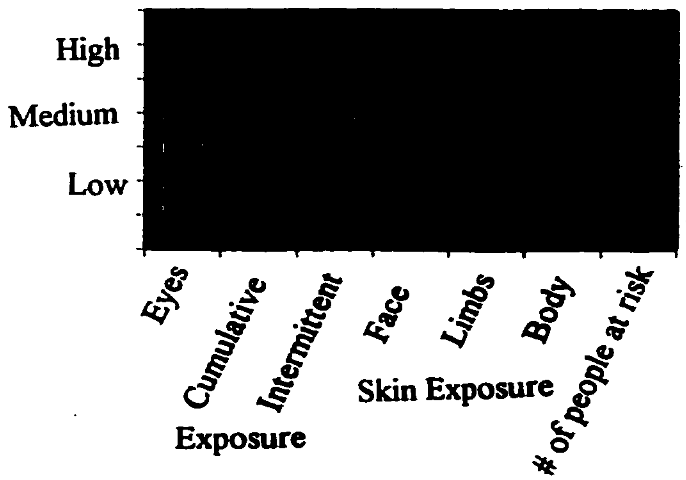


UVR becomes high risk in Zone 3, as the coriolis effect of the rotating earth results in a thinner atmosphere (and therefore less ozone naturally) in conjunction with the polar vortex and increased ozone depletion. The UV-B ground flux and BAD are highest in Zone 3. There is also a much higher albedo, but latitudes found in Zone 3 possess a lower maximum temperature potential (average temperature for July: is 6 degrees Celsius, with an April to August average: - 3.8 degrees, compared to zone 1: + 3.6), reducing risk of exposure to body parts excluding the face. The number of sunlight hours is high (May, June, July, August average 24 hours), but risk from the solar zenith is low and constant, therefore the risk from sunlight hours is medium.

Figure 23 illustrates factors of vulnerability for Zone 3. The eyes are most vulnerable in Zone 3. There is a high albedo combined with long sunlight hours, exposing the eye to prolonged doses of UVR. Cumulative exposure is high, but only for the face, as temperatures do not reach high enough to result in vulnerability to the limbs and rest of the body. Intermittent exposure is rated medium as the Inuit in Zone 3 are in almost complete darkness for half the year, then are exposed to 24 hour light for nearly 4 months.

Moving north in latitude, the number of people who are vulnerable decreases. Vulnerability increases moving south as there are more people potentially affected by UVR, and also a higher number of Caucasians who are more vulnerable to UVR.

Figure 23. Factors of vulnerability: Zone 3.



The body seems to be most vulnerable in the face, and specifically the eyes. Virtually no research has been undertaken in Nunavut to study UVR and the eyes. There is no registry for cataracts. Thirty-four percent of NWT Natives have been to an optometrist, comparable to a very similar Canadian average of 35% (Diverty *et al.*, 1998: 51).

The risks and vulnerabilities from UVR displayed in Figures 18 to 23 are generalizations for each zone, possessing variables or factors of greater or lesser risk in comparison to the other zones. The challenge is to relate the risks per zone to the population inhabiting them. It can be argued that the overall risk may even out over the three zones, yet, for specific variables, the public in each zone must be made aware of their risks, as they differ from Southern Nunavut to Middle Nunavut to High Nunavut.

Certain predictions can be estimated using data collected within the zones. Scenario predictions for the future may be helpful in assessing risk for Nunavut, regarding UVR and health. A continued decrease in ozone over Nunavut is expected, resulting in a continued increase in UVR penetration, and therefore human exposure. This will increase the risks of cataracts and immunosuppression. The probability of a skin cancer increase is hard to gauge due to the skin type of the Inuit, which protects well against UVR. However, the number of sunburns reported is increasing, concurrently increasing the risk of skin cancer. Erythema is one of the first steps in the development of skin cancer, illustrating that the Inuit are also vulnerable to UVR and possibly skin cancer.

The risk from albedo may decrease in the future, as global warming may take a predominant role in the Arctic. If global warming models are correct, the greatest temperature increases will occur in the winter. This may reduce snow and ice, or may result in a greater snowfall; the outcome is unknown. If summer temperatures rise, this may result in the wearing of less protective clothing, increasing exposure. There may be less snow as ground cover, as snow or ice may melt sooner or quicker, reducing albedo. The increasing and prolonging of summer temperatures will increase the risk of cumulative exposure to UVR, relating to immunosuppression, BCC, SCC and cataract development. Vulnerability, linking health care to rural areas can be shown in hospital beds per person. The average for Nunavut is 1 bed for every 235 inhabitants. For Kitikmeot, with its 100% rural population, there is 1 bed for every 308 people. For Baffin, with 61% of its population rural, there is one bed for every 200 residents. This is a substantial difference, leaving rural populations with less health care than urban residents.

Perception of health care in the NWT territories differs from Native to Non-Native populations, as well as with provincial averages. Forty-seven percent of Native residents of the NWT feel the health care system is excellent or good, compared to 75% of Non-Native NWT residents. Twelve percent of Natives feel the system is fair or poor, compared to 6% of Non-Native residents. If the perception is that of a lower quality health care system among Natives, than less Native people will feel that turning to the health care system is a viable option, leaving this segment of the population more vulnerable to illness and disease.

There seems to be a false sense of security that a cold Arctic environment has a low UVR risk, when in fact temperature has nothing to do with UVR penetration and the UVR risk is high. This may result in the population of Nunavut feeling they are not vulnerable to UVR, ignoring precautions and further increasing their actual risk from UVR. For the present, this baseline information contained in the scenario zones will assist educators by bringing the concepts of risk and vulnerability to the fore.

CONCLUSIONS AND RECOMMENDATIONS

Section 6 will offers conclusions drawn from the thesis. The state of the knowledge of UVR and health will be summarized regarding physical factors and human health, reinforcing the complexity and uniqueness of Nunavut. Based on these conclusions, recommendations will be made addressing risk to, and vulnerability of the population of Nunavut.

a) Conclusion

Nunavut possesses a unique Arctic Canadian environment and ecology, that through intricate interrelationships offers a complex challenge regarding the study of the variables presented in this thesis; the land itself is vulnerable due to its uniqueness. The full threat of UVR is unknown at this time, however the predicted threat to human health is large, but as very little research in this area has been undertaken, the population of Nunavut is at varying degrees of risk from UVR.

Geographical factors are predominant variables with regard to risk and vulnerability in Nunavut. The complexity of interactions these factors possess is unique to Arctic environments. Latitude is therefore the deciding and most influencing factor. The high latitude of Nunavut determines the temperature, extent of permafrost, solar zenith, sunlight hours, atmospheric circulation patterns and therefore ozone depletion and levels of UVR penetration. These factors which helped shape Inuit culture, with the exception of anthropogenically assisted ozone depletion, are based on latitude, the population of Nunavut is vulnerable, as they cannot alter these variables, merely adjust lifestyle to protect themselves from these factors.

The population of Nunavut averages 72 % Inuit, but is greater than 90 % in most communities. This is unique from any other political territory, state or province. The Inuit have a different culture from southern Canada, as well as a specialized physiology, which has adapted over thousands of years to the harsh Arctic environment where the Inuit survive. The size of Nunavut provides problems of accessibility, where a population of roughly 24,000 is scattered over 1.9 million square kilometers, with a density of 0.01 person per square kilometer.

The territory of Nunavut was made official April 1, 1999. The territory is very young and is in transition. The transition of power and responsibilities from the NWT and the government of Canada will take time to complete. Until that process is complete, a greater than normal percentage of time and energy will be devoted to infrastructure creation and enhancement instead of other issues. Nunavut is also in transition ecologically. Atmospheric circulation patterns, as well as an increased industrial presence continue to bring new environmental problems to the Arctic.

Lifestyle and physical geographical factors combine to pose great risks to the Inuit and other residents of Nunavut. In the winter there is little or no sunlight and hence, little or no UVR exposure. Spring brings longer sunlight hours and increased UVR exposure. Increased temperatures result in the wearing of less protective clothing, where skin has the potential to be exposed to UVR for nearly 24 hours of the day. Children are especially vulnerable to UVR. Traditionally, Inuit children have much freedom from parents, and may not be monitored while playing. If children are not protected from the sun, they may also be exposed for long periods of time to UVR, increasing risk for the development of cataracts, immunosuppression, and depending on skin type and genetics, skin cancer later in life.

The most deadly form of skin cancer is MM, which is believed to develop from intermittent exposure to UVR; intermittent doses are considered to be more intense levels of exposure than a person is normally subjected to. Cumulative exposure is believed to increase the risk for basal cell carcinoma and squamous cell carcinoma. Both BCC and SCC have a higher number of total cases in comparison to melanoma in Caucasian populations, but are more easily cured. The darker skin type of the Inuit is believed to offer greater protection from the sun's ultra violet rays. In the Inuit, both intermittent and cumulative exposure may increase the risk or promote immunosuppression, damage to the eye, wrinkling, premature ageing of the skin, and negative affects regarding medication and cosmetics.

As no studies have been conducted on Inuit physiology in terms of UVR exposure, the actual effects on Inuit immunosuppression, eye damage and skin type are unknown. Evidence from other regions and populations throughout the world support the view that the risk is great and needs to be addressed.

Risks specific to the Inuit lie in their physical world, culturally, and through the government. Physically the Inuit, and the rest of the population of Nunavut, are at risk from the polar vortex and circulation patterns, increased ozone thinning (specifically stratospheric ozone), increased UVR penetration, Arctic albedo and UVR, extended periods of summer sunlight hours, increased summer temperatures (possibly enhanced by global warming), and the solar zenith in conjunction with ozone depletion.

In the summer, many Inuit and others, return to the land to camp and hunt. This action also coincides with the time of year when risk factors are the greatest, as shown in Figure 16 and Table 24. The hunting and gathering of country foods leads to this exposure. The animals that are hunted may also be affected by UVR (cancers, cataracts, immunosuppression); UVR may, over time affect the traditions of the Inuit, as well as their health. These affects can be seen throughout the food chain, beginning at the bottom, with plankton.

Traditionally, the Inuit have been nomadic. There is a movement now in Inuit society to return to their roots and traditions. Today, 71% of the population of Nunavut reside in rural areas. This raises the question of accessibility of those residents to amenities of urban areas, specifically health care. Kitikmeot's population is 100% rural and has 1 hospital bed for every 308 people, compared to Baffin region, which has 61% of it's population in rural areas, and has 1 hospital bed for every 200 people. In rural areas, there may also be lowered access to employment, helping explain the high number of people (57.3%) categorized in "other" employment and their need to hunt country foods.

Store bought foods are generally three times more expensive compared to the rest of Canada, and also do not have the nutritional value of country foods.

When questioned about UVR and policies of prevention and protection, the health offices of the Nunavut government did not consider UVR a problem. Part of the reason is that there are higher priorities and there is virtually no research on Nunavut or the Inuit regarding UVR. This leaves a large population and area vulnerable.

This thesis has gathered baseline data from various backgrounds and disciplines, combining factors to produce risk and vulnerability outcomes. The process is difficult as the data are so varied. Future research is required in attempting to study the problem of UVR and health in Nunavut. An interdisciplinary approach is necessary in dealing with this complex problem in the unique environment of Nunavut.

b) Recommendations

The goal for this thesis was to produce a set of baseline data as indicators of risk, which could be built upon in the future, incorporating Western and traditional views to lay the groundwork for culturally sensitive strategies for management and education of UVR and health in Nunavut. "To determine if a disease or hazard is caused and not merely associated with climate change relies on the quality of data and study types" (Gillis *et al.*, 1994: 199).

The health offices of Nunavut seem unconcerned with UVR and health, through people seem to be noticing a "sharper sun" and are developing sunburns. It is suggested the public be made aware of the threat of UVR, through the health offices and provincial and federal government institutions. This could be done through government advertising campaigns. At this point in time, the risk of UVR is not considered great enough to warrant action for prevention and protection. This could be remedied by increased research on UVR and health in Nunavut. Also, other issues may be higher priorities, such as sexually transmitted diseases and suicides, as the outcomes from these health effects are more immediate.

This section will outline recommendations drawn from the conclusions of this thesis. First, any future research undertaken in this area of study should approach the problem using an integrated assessment, where "the boundaries of research are determined by the problem, not by disciplinary expertise" (IASC, 1996: 30). These recommendations fall within 4 generalities:

1. Conducting of in-depth research in factors of risk regarding UVR and health.
2. The need to monitor, record, organize, and assess outcomes from research.
3. Inform and educate the public in a culturally sensitive manner.
4. Address vulnerability of Nunavut, due to complexity and uniqueness.

The need for studies that pertain specifically to Nunavut and the Arctic environment is a necessity. Research on UVR and health from southern latitudes and predominantly Caucasian populations, cannot be transferred directly to a unique Arctic situation (IASC, 1996: 25). Within Nunavut, there is the need for research in 6 general areas:

- Continue to monitor UVR penetration and ground level flux in conjunction with ozone monitoring; the continuation of ozone and UVR databases is necessary to establish trends and examine the probability of correlations to health.

- The effects of global warming in the Arctic, specifically pertaining to temperature and albedo, and hence exposure levels for those on the land, should be monitored.

- Studies involving all members of the population, especially the Inuit, regarding immunosuppression, skin cancer (non-melanomic and melanomic), cataracts, skin thickening, lesions or rashes (actinic keratosis, a good UVB measure of exposure (IASC, 1996: 26)), warts (human papiloma virus (IASC, 1996: 27)) or skin funguses on sun exposed areas on the body are necessary. Also, DNA blood testing to study the possibility of genetic susceptibility of subjects to skin cancer, and other medical variables thought to be caused by environmental factors (DeFabo, 1999) are recommended. None of these factors have been studied in a Canadian Inuit population, or any population at Arctic latitudes.

- Lifestyle is an important factor regarding risk of exposure to UVR. Surveys and data collection are required in Nunavut regarding occupation, time spent out of doors, sun protection attitudes (or lack thereof) and recreation habits. As well, anecdotal information from elders of Inuit communities is vital to assess the natural history of the problem. As Inuit traditional knowledge is passed on through generations verbally, a reliable source for bioclimatilogical and educational information exists.

- A comparison of certain aspects of populations at risk, possessing similar skin types to the Inuit (China, Japan), comparing culture, outdoor exposure habits, latitude, genetic histories, and genetic similarities, may provide insight to UVR and health that otherwise may not be readily apparent.

- Studies are necessary on the ecological effects on the Arctic environment, the land, its flora and fauna, which the Inuit depend on (culturally and physically) and UVR including: animals, especially those which are depended upon as country foods, building material decay, possible chemical reactions in the atmosphere, socio-economic impacts, and the possibility of insects as monitors. Compared to the rest of Canada, roughly 1 / 15 of the average Canadian insect diversity is found in the Canadian Arctic (Danks, 1992: 159). Certain species may be more susceptible to environmental change, therefore making insects a good monitoring tool.

These studies need to be conducted to allow for more accurate conclusions to be drawn on UVR and health in Nunavut. Strong conclusions would allow rapid policy implementation, thereby protecting more people and reducing risk and vulnerability.

Results from studies conducted need to be monitored and cross-referenced. The problem is complex and interrelated, therefore solutions, risks, and hazards to one section of the problem may lay in other aspects of study. The following recommendations include the recording, organization, and assessment of the data.

- There is a need for the creation of registries for diseases and health problems relating to UVR. Currently, skin cancer is the only UVR related disease that is recorded in Nunavut. Registries for cataracts, herpes, DNA testing, and if possible, skin lesions and rashes on sun exposed parts of the body would aid research. Recording skin type would aid in correlations to physical environmental variables. As well, if data were recorded by community of origin, latitude may be considered a factor of risk when compared to incidence rates. It may take years to connect UVR to cataracts and skin cancer in Nunavut (the skin cancer registry's first complete year of data in Nunavut was 1990) as there is a significant lag time in development.

- The creation of databases for ongoing surveys of the population regarding exposure habits, perceived and actual effects of UVR.

The monitoring, recording, and organization of results and data will allow for easier access to collected data, and therefore increased capacity for secondary research. Once a problem has been researched and data analyzed, the public should be informed of the information. When informing the public, considerations of physical geographical location, and an area's cultural and social geography should be taken into account.

Education is the main focus when informing the public, as it is not a fleeting message, but something that may alter action and lifestyle.

> Adult education is the key to health, not education in the academic style...but basic public education about health, hygiene, nutrition, parenting, managing a household, and so on. We assume everyone knows these things, but many do not - including the Inuit, who used to live off the land in a very different lifestyle. They are now living with white traditions and were never taught how to live this way (BRP, 1994: 21).

The following are recommendations for informing the public of Nunavut through education:

- Information and education regarding UVR exposure and health should come from the public health office, and be addressed in: schools, as curriculum, through advertisement campaigns (billboards, radio, posters, newspapers, television, news and weather updates), a visible UV index distribution system (not merely a recording on a phone line, which describes the day's weather), and through community organization. using community leaders to make the risk from UVR apparent. When addressing UVR as a health concern, its position as a health priority should be observed, in terms of other health and social problems (alcohol, STD's, HIV, suicide) and budgeted for.

- It is recommended that content for public education and information made available should include: increased UVR risk specific to the physical environment in which a community occupies, hours of peak exposure, protective clothing as a preventative measure, the risk and dangers of sunburn, protection from UVR (sunscreen to prevent erythema, sunglasses), and when, where and how to receive help or information. How to identify potential malignant growths on the skin using the skin monitoring technique A, B, C, D, E (a self examination for growths focusing on asymmetry, border irregularity, colour, diameter, and elevation), and detecting any change or new growths. All programs of educating and informing the public should be diligent in making messages relatable to Inuit culture, possibly including the notion that the body and spirit are interconnected, and how UVR health affects fit into that relationship.

- Sensitivity to the Inuit situation is vital in Nunavut. Planning and careful cultural considerations, including behaviour are required in Nunavut.
  A low pressure method of public education would best suit Nunavut. Those delivering this message would be advised to conduct themselves in a manner that suggests they are "not here to conquer", but to spread a message. Ideally, Inuit community members (traditional healers, Inuit community nurses, community leaders) would undertake the front-line role of educating. Once again, UVR should be placed within the mindset of the Inuit, therefore describing the role of UVR in terms of the interconnectedness of the Inuit, the land, and the flora and fauna present.

The problem of UVR is complex in Nunavut. Attempting to lend evidence supporting the possibility of negative health effects from UVR in humans, with scarce and limited data has been inconclusive. However, the threat warrants the education of the public to the possible risks of UVR. This information should be passed along, although statistical links in Nunavut are absent.

The Inuit are left vulnerable to the impacts increased rates of UVR may have on pollutants and chemicals in the atmosphere over the Arctic. The physical geography of the Arctic, unfortunately leads to the concentration of the northern hemisphere's pollutants at the north pole. Effects from UVR also impacts the animals on which the Inuit rely for food. UVR may not only alter aspects of Inuit health, but also their culture.

The Inuit sparsely populate a very harsh environment, where travel is a difficult undertaking, as modern transportation routes are not established. The most common way of travelling across large distances in Nunavut is by plane. The Inuit are vulnerable in terms of accessibility, specifically regarding health issues. Lower accessibility leads to a lower probability of rapid diagnosis, resulting in later detection of disease or illness. This may lead to less effective treatment, as health problems may be more advanced when a person is ultimately seen by a health professional. This may lead to an under serviced population in Nunavut; a potentially deadly problem if there is a rise in malignant melanoma, as the Inuit are now beginning to complain of erythema, a precursor to skin cancer in fairer skinned populations. Unfortunately, this hypothesis cannot be confirmed until decades into the future, as there is a great lag time in skin cancer development. The problem of a sparse and possibly under serviced population, is compounded as the health offices of Nunavut have not recognized UVR as a serious health threat.

The continuity of health care is also an area of vulnerability. Doctors, dermatologists, and opthamologists are generally in communities for short periods of time. There is little time in which to build doctor - patient trust and relationships. As well, when new doctors are assigned to a region, they may not have the time to review all patient histories, thereby leaving patients at risk. There are also no registries for their practices, leaving no data to study for trends of disease and for linking to environmental factors.

There is also a concern regarding the time allotted for emotional support, from physicians to patients with serious illness. The number of beds per person available within the regions of Nunavut are also of concern, as there seems to be an under serviced population in Kitikmeot (1/308), compared to Baffin (1/200), and the average for Nunavut (1/235).

The perception of health care in Nunavut indicates vulnerability of the population. The provincial average for people who feel their health care system is poor or fair is 6%. In the former NWT, among Native populations, this value rose to 12%. There was also a lower number of people in the NWT that considered the health care system excellent or good. If health care is perceived to be inadequate, whether in reality it is or is not, is not the issue. The issue is how to improve the system so that over one-tenth of the population does not feel alienated from a system to provide, help, and heal them.

The continuing of present ozone and UVR research, with the addition of new areas of study, will aid in bringing to light evidence supporting links to the negative effects of UVR on human and environmental health. The monitoring, cross referencing, and recording of this information will make further research and secondary data analysis more simple and accessible. The education and protection of life is the ultimate goal of this research. The baseline data on physical and cultural factors collected in this thesis, is a starting point for continued research that is required in Nunavut and the Arctic.

Appendix A Nunavut communities, population and latitude

Baffin region communities, population and degrees north latitude:

• Iqaluit	4,220	;capital of Nunavut with regional hospital
• Arctic Bay (Ikpiarjuk)	639;	73 degrees
• Broughton (Qikiqtarjuaq)	488;	67 degrees
• Cape Dorset (Kinnigat)	1,118;	64 degrees
• Clyde River (Kangiutugaapik)	708;	70 degrees
• Grise Fiord (Ausuituq)	148;	76 degrees, 1980km north of Iqualuit
• Hall Beach (Sanirajak)	543;	68 degrees
• Igoolik (Iglulik)	1,174;	69 degrees
• Nanisivik	287;	73 degrees
• Pangnirtung	1,243;	66 degrees
• Pond Inlet (Mitimatalik)	1,154;	72 degrees
• Lake Harbour (Kimmirut)	397;	63 degrees
• Resolute (Quusuituq)	198;	74 degrees
• Sanikiluaq	631:	56 degrees
Total Population: 13,218	rural: 8,057	urban: 5,161

Keewtin region communities, population and degrees north latitude:

• Arviat	1,559;	61 degrees
• Baker Lake	1,385;	64 degrees
• Chesterfield Inlet	337;	63 degrees
• Coral Harbour	669;	64 degrees
• Rankin Inlet	2,058;	62 degrees
• Repulse Bay	559;	66 degrees
• Whale Cove	301;	62 degrees
Total Population: 6,868	rural: 4,810	urban: 2,058

Kitikmeot region communities, population and degrees north latitude:

• Bathurst Inlet	18;	66 degrees
• Cambridge Bay	1,351;	69 degrees
• Gjoa Haven	879;	68 degrees
• Kugluktuk	1,201;	67 degrees
• Pelly Bay	496;	68 degrees
• Taloyouk	648;	69 degrees
Total Population: 4,626	rural: 4,626	urban: 0

( ) = Inuktitut names

(source: Statistics Canada, Population and dwelling counts, 1997)

Appendix B: Ozone data.

Churchill	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Average
1987	N/A	440	396	399	380	353	338	343	296	315	N/A	N/A	362
1988	393	412	429	402	374	329	338	318	301	300	311	N/A	355
1989	N/A	371	454	426	358	346	325	300	294	326	N/A	N/A	356
1990	N/A	464	381	N/A	321	345	329	310	296	338	306	310	340
1991	427	423	458	424	368	345	341	308	299	322	321	303	362
1992	479	420	407	394	367	352	340	309	315	316	323	301	360
1993	391	380	380	379	353	329	317	303	309	305	N/A	N/A	345
1994	437	421	424	420	370	346	336	308	290	299	327	N/A	362
1995	N/A	N/A	N/A	N/A	366	320	336	313	N/A	N/A	N/A	N/A	334
1996	346	N/A	382	401	370	341	321	302	290	298	297	351	336
1997	369	410	434	410	382	348	324	313	N/A	300	N/A	367	366
1998	391	401	432	405	380	N/A	N/A	N/A	N/A	N/A	N/A	N/A	402
Average*	404	414	416	406	366	341	331	312	299	312	314	326	353

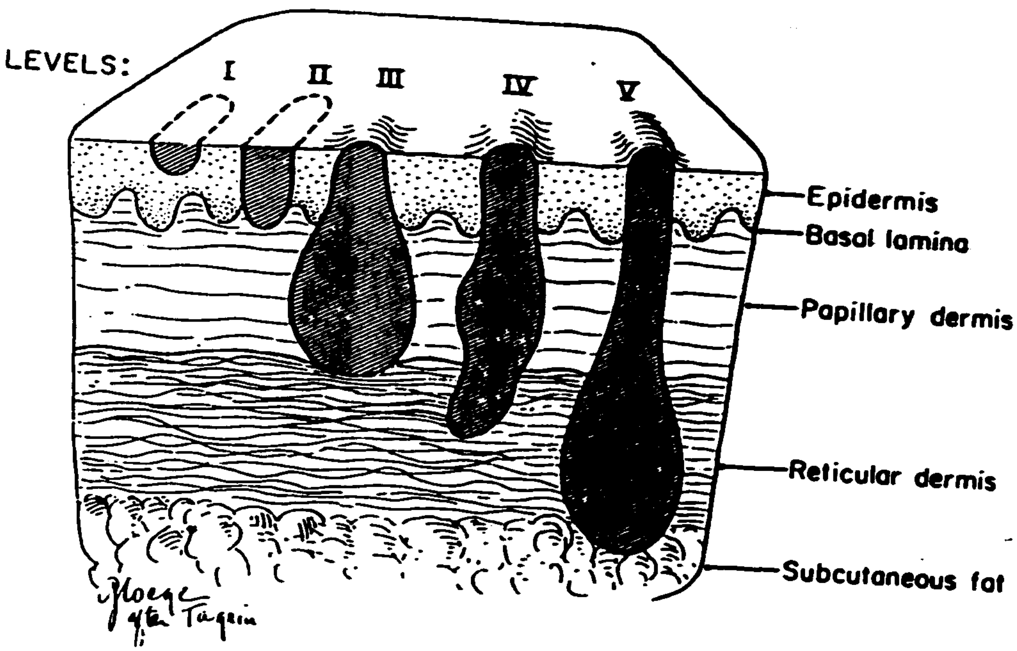
Resolute	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	
1960/65/70	429	455	447	490	419	380	339	340	292	313	344	405	388
1987	N/A	N/A	N/A	N/A	373	366	348	330	365	370	415	429	375
1988	428	447	465	444	414	359	320	312	311	N/A	393	310	382
1989	374	384	509	454	419	352	322	285	291	353	382	375	375
1990	337	529	437	403	394	364	333	305	319	343	N/A	330	372
1991	430	N/A	486	426	387	365	340	318	298	326	375	N/A	375
1992	463	N/A	433	432	405	352	330	305	327	347	379	386	378
1993	371	375	365	399	352	338	298	298	283	330	337	388	345
1994	392	377	446	448	384	381	332	292	305	287	423	349	368
1995	350	418	407	384	382	341	325	311	314	316	N/A	343	354
1996	332	364	451	429	373	358	314	311	278	291	328	359	349
1997	396	356	338	406	398	349	323	328	293	301	303	362	346
1998	393	383	466	445	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	422
Average*	388	404	437	425	389	357	326	307	308	326	371	363	367

Alert	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	
1958	252	468	495	459	417	344	323	281	291	316	356	N/A	364
1987	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	347	280	404	344
1988	411	433	476	427	416	483	354	327	N/A	N/A	345	319	399
1989	318	383	N/A	422	404	N/A	313	291	N/A	311	300	333	342
1990	337	417	N/A	375	390	347	380	287	N/A	N/A	N/A	328	358
1991	372	449	414	N/A	392	374	344	316	330	327	N/A	N/A	369
1992	352	344	387	417	359	334	315	272	264	N/A	N/A	340	338
1993	331	N/A	317	388	352	315	278	280	N/A	299	N/A	N/A	320
1994	N/A	N/A	N/A	436	380	344	326	275	307	N/A	N/A	N/A	345
1995	N/A	N/A	N/A	N/A	N/A	337	302	283	266	N/A	N/A	N/A	297
Average*	354	426	399	411	385	348	327	291	292	321	308	345	351

***: Average does not include 1958, 1960, 1965 or 1970 data or N/A fields.**

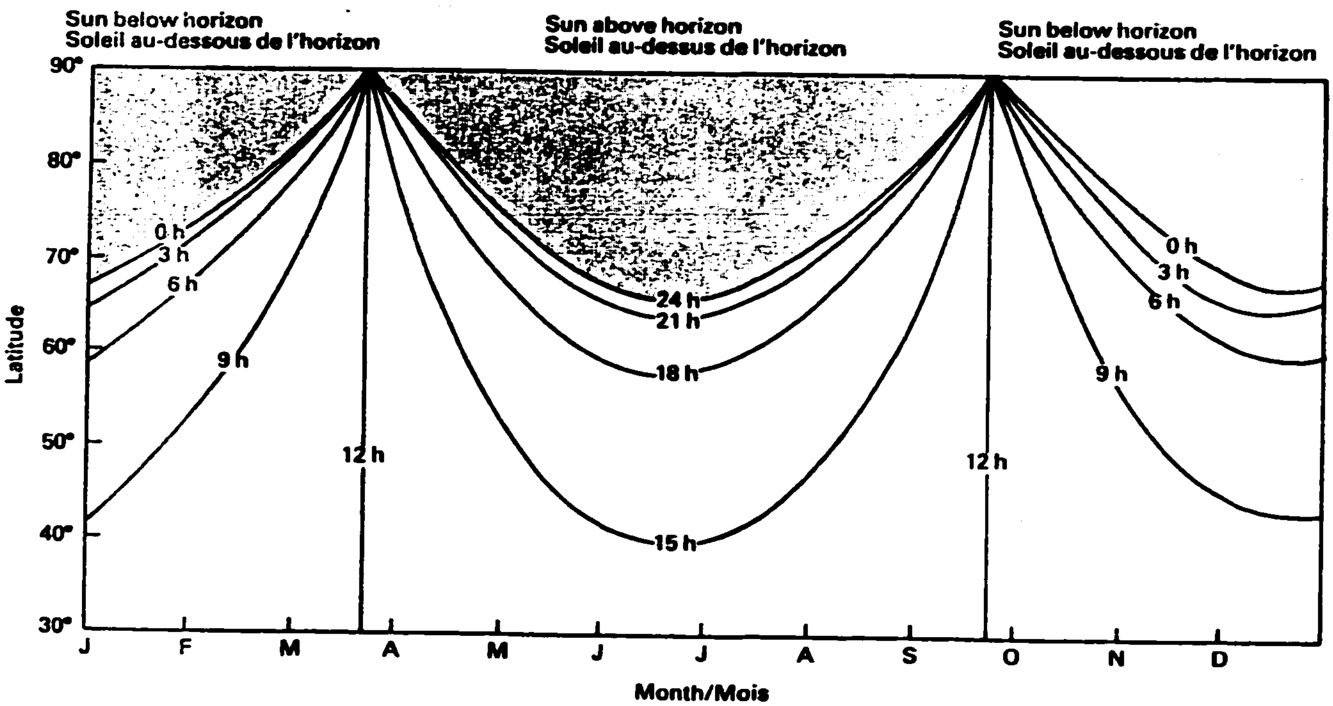
Source: World Ozone Data Centre. 1999.

Appendix C: Clark's level of tumour invasion.



Source: taken from Morton et al., 1993: 1797.

Appendix D: Sunlight hours per month at specific locations.



Source: taken from Maxwell, 1981: 56.

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